THE RELATIONSHIP OF TEMPERATURE INVERSIONS TO MARINE ADVECTION FOG

Robert Jerome McClure

Report Number--NPS-51MC74091

NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

THE RELATIONSHIP OF TEMPERATURE
INVERSIONS TO MARINE ADVECTION FOG

by

Robert Jerome McClure

September 1974

Thesis Advisor: C. L. Taylor

Approved for public release; distribution unlimited.

Prepared for: Naval Air Systems Command
Washington, D.C. 20360

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER NPS-51MC74091	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) The Relationship of Temperature Inversions to Marine Advection Fog		5. TYPE OF REPORT & PERIOD COVERED Master's Thesis September 1974
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Robert Jerome McClure In conjunction with Charles L. Taylor		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Postgraduate School Monterey, California 93940		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 62755N; P04-1027 62759N; P05-1051
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Air Systems Command Washington, D. C. 20360		12. REPORT DATE
		13. NUMBER OF PAGES 91 Pages
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Fog (West Coast), Inversion

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The purpose of this study was to search for a consistent link between temperature inversions and the occurrence of marine advection fog, in order that the temperature inversions could possibly be used as a forecasting aid at coastal stations. A data base of 10 months, July 1973 to April 1974, was used in the study, covering the summer, fall, and winter seasons. The

inversion parameters investigated were the height of the inversion base, thickness of the inversion layer and the temperature gradient within the inversion layer.

A relationship between the change in inversion parameters and the occurrence of fog was found to exist at San Diego, California, in the summer and winter seasons. At Oakland, California, consistency in the change of at least one parameter was found in the summer and fall seasons, and the first two months of the winter season.

NAVAL POSTGRADUATE SCHOOL
Monterey, California

Rear Admiral Isham Linder
Superintendent

Jack R. Borsting
Provost

This thesis prepared in conjunction with research supported in part by NAVAL AIR SYSTEMS COMMAND under PO 4-1027 issued 26 July 1973, and PO 5-1051 issued 18 June 1974.

Released as a
Technical Report by:

The Relationship of Temperature Inversions to Marine Advection Fog

by

Robert Jerome McClure
Lieutenant, United States Navy
B.S., United States Merchant Marine Academy, 1968

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN METEOROLOGY

from the

NAVAL POSTGRADUATE SCHOOL
September 1974

ABSTRACT

The purpose of this study was to search for a consistent link between temperature inversions and the occurrence of marine advection fog, in order that the temperature inversions could possibly be used as a forecasting aid at coastal stations. A data base of 10 months, July 1973 to April 1974, was used in the study, covering the summer, fall, and winter seasons. The inversion parameters investigated were the height of the inversion base, thickness of the inversion layer and the temperature gradient within the inversion layer.

A relationship between the change in inversion parameters and the occurrence of fog was found to exist at San Diego, California, in the summer and winter seasons. At Oakland, California, consistency in the change of at least one parameter was found in the summer and fall seasons, and the first two months of the winter season.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACKNOWLEDGEMENT

The author wishes to express his appreciation to his thesis advisor, Professor C. L. Taylor, for this suggestions, advice and guidance in this study.

Gratitude is expressed, also, to Mr. P. R. Adler for work done in the initial organization and maintenance of the data.

Finally, the author wishes to express his appreciation to his wife for her support and for her assistance in typing the rough draft of this thesis.

I. INTRODUCTION

Marine advection fog is a type of fog that is formed offshore, and is moved to the coastal regions by local winds. The advection of warm moist air over a cold surface, and the consequent cooling of that air to the dew point is the basic process by which such fog is formed. During the summer, this fog type occurs in air which passes over the cold ocean water just off the west coast of the continental United States. Though this applies mainly to California localities, it can also apply to areas further north on the Oregon and Washington coasts. Winter fog is not as strictly tied to the advection type as in the summer season. In winter, frontal and pre-frontal fogs occur with the movement of cyclones and their associated weather systems through the west-coast area. Advection fog would occur when southerly winds bring warm air northward over colder water.

It has been recognized, in studies of the southern California stratus and fog, that the vertical temperature profile can reflect the formation and behavior of this advection fog. The purpose of this thesis was to search for a consistent link between temperature inversions and the occurrence of marine advection fog, such that the pattern of temperature inversions could possibly be used as a forecasting tool at coastal stations.

The study was done using the three Pacific coast upper-air sounding stations, i.e., San Diego, California; Oakland, California; and Quillayute, Washington. Fog Data were obtained from surface hourly observation stations associated with the upper air stations (see Table I). Current data were used beginning with July 1973 and ending with April 1974. Data for May and June of 1974 were not available in sufficient time for this study. Nondiurnal changes were investigated since diurnal changes are considered to be cyclic, and not as definitive of parameters from day to day.

Upper Air Sounding Station	Surface Observation Station	Index No.	Call	Latitude	Longitude	Elevation (ft)	Elevation (m)	Distance Between (nm)
San Diego, Ca. Montgomery Fd.		290	SAN	N32-49	W117-08	408	(124.4) 124	5.4
	San Diego, Ca. Lindberg Fd.	290	SAN	N32-44	W117-10	28	(8.5) 9	
Oakland, Ca. Int.Airport/UAU		493	OAK	N37-45	W122-13	18	(5.5) 6	1.3
	Oakland, Ca. Int. Airport	493	OAK	N37-44	W122-12	7	(2.1) 2	
Quillayute, Washington		797	UIL	N47-57	W124-33	205	(62.5) 63	95.7
	Seattle/ Tacoma, Wa. Int. Airport	793	SEA	N47-27	W122-18	450	(137.2) 137	

TABLE I. Surface Observation and Upper Air Sounding Stations

II. BACKGROUND MATERIAL ON MARINE ADVECTION FOG FORMATION AND TEMPERATURE INVERSION RELATIONSHIPS

In 1948, Leipper [4] presented a model of fog development for San Diego, California. It was a four-stage model for the winter. The first stage called for the presence, over the sea, of air with temperatures higher than the sea surface temperature, and dry air aloft. This provides the initial conditions necessary for the formation of a surface inversion which would then restrict the vertical movement of moisture. Therefore, a shallow lower layer of air will approach saturation. The dry air aloft permits rapid cooling of the surface layer by radiation, and intensifies the fog.

In the second stage, the surface inversion forms. Near saturation occurs in the lowest air layers at a temperature close to that of the sea surface. The heat content of these layers decreases due to conduction of heat downward. Fog forms in the third stage. This is due to the passage of the nearly saturated air over colder coastal waters. If this does not form fog, the changes bring the lower layer of air into a condition where large amounts of heat are lost by radiation from the moist air, and fog will form this way. The fourth, and last, stage is marked by the deepening of the lower, nearly adiabatic, layer to approximately 400 meters or more. The inversion is still present, and restricts the vertical movement of moisture. As the marine layer below the

inversion deepens, a point is reached where the moving and cooling processes do not result in condensation throughout the entire layer. Fog no longer forms at the ground, and the fog sequence ends as a stratus regime begins. This fog sequence usually extends over a period of approximately five days.

In a 1968 paper by Leipper, the increasing thickness of the fog layer off-shore, and its subsequent advection all the way into the coast at San Diego, California, is discussed. The advection fog has formed at sea due to warm moist air moving in over colder water. The fog layer becomes cooler than the ocean surface due to radiational cooling, so there is warming from below and cooling from the top of the fog layer. A super-adiatatic layer, as observed by Edinger [2] is formed, and the mixing within this layer causes the thickness of the fog layer to increase from day to day. The strongest onshore wind, bringing the fog in, comes at the time of day of the sea breeze. This implies that late afternoon is the most likely time for fog to be brought all the way into the shore. However, the thickness of this fog layer is indicative of whether or not it actually reaches the coast. It must be deep enough in order for the wind to drive the fog towards the shore. Also, the heat of the land will dissipate a thin layer of fog, and when the sea breeze stops for the day, the fog will retreat. Eventually, the unstable fog layer becomes thick enough that it cannot be dissipated as it moves into the land areas.

In the "Final Report of the Fog Project" conducted at Scripps Institution of Oceanography, and published in August, 1948 [5], J. B. Wickham expresses the importance of the height of the inversion base in fog forecasting. If a dry air mass exists over a water surface, an upward moisture gradient will exist, implying an upward flux of moisture will occur. When a nearly adiabatic surface layer underlies a strong temperature inversion, the moisture flux through the inversion is insignificant in comparison to the flux through the surface layer. Therefore, the moisture content of the surface layer is increased. If this process continues, near saturation of the entire adiabatic layer can take place, providing there is no change in the temperature structure. The lower the inversion, the more rapidly near-saturation is attained. The height of the inversion base also determines the amount of cooling necessary for condensation and fog formation to occur. For a surface adiabatic layer near saturation, the thicker this layer (higher the inversion base), the more cooling required for fog formation.

In a 1968 study by Rosenthal [12] off the southern California coast, the inversion base was shown to be lower, stronger and more persistent in the summer months. This is due to the semi-permanent sub-tropical high pressure cell over the northeast Pacific Ocean. Cool, moist, marine air flows into the coast at the surface. The general circulation pattern, due to the high pressure area, has air moving down the slopes of the coastal mountains toward the shores. This air warms

in its descent. The consequence of the general system is a persistent, moderate subsidence. Combined with the cooler marine flow, a persistent inversion results.

During the spring and fall seasons, the vertical motion of the inversion was found to be influenced by trough and frontal passages. The inversion rises with the approaching system, and subsides after passage. The inversion will usually dissipate during descent, and a new low-level inversion will often form due, presumably, to low-level subsidence.

The winter period is the time of year when troughs and frontal systems are the strongest. The changes in height of inversions can be quite rapid, and when present, are usually weak. Inversions can be absent for several days if there are several troughs aloft moving through the area.

It was Rosenthal's assessment [12] that inversion height and strength parameters would seem to be indicators of the occurrence or non-occurrence of stratus.

III. DATA PROCEDURE AND ANALYSIS METHODS

A listing of all fog periods and durations was compiled from the hourly surface observations at the three stations, i.e. San Diego and Oakland, California, and Seattle-Tacoma, Washington. From this listing specific periods of fog, which had sufficient sounding data available, were selected for analysis. In general, the period from three days prior to the onset of a fog occurrence or sequence, to one day after its termination, was analyzed. Three such periods, then, were selected from each season, one from each month if possible.

Teletype reports from the upper-air sounding stations at San Diego and Oakland, California, and Quillayute, Washington provided the vertical temperature profiles used. These radiosonde reports were plotted for the 00GMT (1600Local) and 12GMT (0400Local) soundings, up to 850-mb. From these, the following data were extracted:

1. Height of the inversion base in millibars.
2. Height of the inversion top in millibars.
3. Height of the 1000-mb level in meters.
4. Height of the 850-mb level in meters.
5. Temperatures in degrees centigrade at the:
    a. Surface
    b. Inversion base
    c. Inversion top

From this extracted data, the following inversion parameters were computed for all the selected soundings:

1. Temperature gradient of the inversion in degrees centigrade per kilometer.
2. Height of the inversion base in meters.
3. Height of the inversion top in meters.
4. Thickness of the inversion layer in meters.

NOTE: The above heights were found using the pressure-altitude curve method on the AROWAGRAM, until recently the Naval Weather Service's standard thermodynamic chart.

Graphs, for the selected periods, of the height of the inversion base, the thickness of the inversion, and its temperature gradient were plotted for three cases.

1. 12-hour changes from sounding to sounding.
2. 24-hour changes from 00GMT to 00GMT.
3. 24-hour changes from 12GMT to 12GMT.

Individual fog occurrences are depicted in block form on these graphs. Missing data points are by-passed with dashed lines connecting points of known data. Points of data that exist without adjacent points are circled.

The 24-hour change in the 00GMT and 12GMT sounding were depicted for the duration of each analyzed period. Shaded areas indicate apparent warming during the past 24-hours; unshaded areas indicate apparent cooling.

Using the selected periods, each season was analyzed separately with regard to consistency of the three inversion

parameters and general thermal trend of the sounding. Where consistency in the selected cases was found, these results were checked against the remaining fog cases. The final results of this analysis are written in the next section.

TABLE II

FOG DATA AT SAN DIEGO, CALIFORNIA

Mo./Yr.	Fog Days	Percen. of Month	Fog Hours	+2 Hour* Fog Days	% Month	+2 Hour** Fog Hours
Jul 73	7	22.6	47:52	7	22.6	46:52
Aug 73	4	12.9	11:21	2	6.5	9:16
Sep 73	3	10.0	14:20	3	10.0	14:20
Oct 73	8	25.8	66:44	8	25.8	63:36
Nov 73	7	23.3	34:45	5	16.7	31:10
Dec 73	12	38.7	53:44	7	22.6	46:02
Jan 74	7	22.6	57:55	5	16.1	52:45
Feb 74	5	17.9	19:06	3	10.7	17:43
Mar 74	7	22.6	56:28	5	16.1	52:52
Apr 74	7	23.3	29:21	5	16.7	26:18
TOTALS	67	22.0	391:36	50	16.4	360:54
Season		% of Season			% of Season	
Summer	14	15.2	73:33	12	13.0	70:28
Fall	27	29.3	155:13	20	21.7	140:48
Winter	19	21.1	133:29	13	14.4	123:20

* +2 Hour Fog Days: Days containing a fog period more than 2 hours in duration.

** +2 Hour Fog Hours: Total of fog periods greater than 2 hours in duration.

IV. RESULTS

A. SAN DIEGO RESULTS

In the San Diego area, the cloud form most generally observed is stratus. It is so common that the period from late spring to early fall has been named the "stratus season." [9] The differences here, between stratus and fog, are the height of the stratus base and the visibility within. For fog the base would be at the surface, and visibility would be considerably reduced.

Table II contains fog data for San Diego. Of the ten months analyzed, July 1973 to April 1974, the least amount of fog occurred in the summer season, with August 1973 having the least number of hours of fog. The fall season had the greatest number of hours of fog, with October 1973 having the largest number of hours of fog. It should be noted, however, that the month of December 1973, had the greatest number of individual fog days, though only having 80% as much fog, in terms of hours, as October.

For fog periods which began after the 00GMT or 12GMT soundings were taken, the presence of an inversion in the sounding immediately prior to the fog occurrence was examined. Of the available soundings, 93% showed an inversion present. See Appendix A, Figures 1, 2, and 3.

Fog during soundings was examined seperately. Here again, 93% of the available soundings contained inversions. See Appendix A, Figure 4.

For both cases, soundings immediately preceding and during fog, there was a small percentage of cases where there was, or appeared to be, fog without an inversion. These were all late fall and winter cases. All available summer soundings, for these cases, contained an inversion.

1. Summer

Of the three seasons studied, the summer had the least amount of fog, only 73.6 hours on 14 days. Of this, 70.5 hours of fog accounted for fog periods in excess of two hours duration and occurred on 12 of the 14 fog days. A majority of the cases had fog beginning after the 00GMT sounding, between 0001GMT and 1159GMT, and extending through the 12GMT sounding. This would be fog beginning at night, and remaining through the next morning. In all cases, where there were data available, the temperature sounding immediately prior to, or during, the fog contained an inversion. See Figures 1, 2, 3, and 4 in Appendix A.

The 24-hour change in the inversion and its parameters, which takes place between similar soundings prior to fog, shows some consistency. The 24-hour 00GMT sounding change indicated a shrinking thickness prior to fog, but the accompanying temperature gradient change was not uniform. Though movement of the inversion base was generally down, it was not always so for fog beginning after 12GMT. Where fog was to occur for several days, there was a warming trend in the lower atmosphere, associated with a subsiding inversion.

Fog was preceded by cooling of the surface layer, then with each following 24-hour 00GMT change, cooling and a rising inversion persists with the fog days.

The 24-hour 12GMT sounding change showed considerable consistency relative to the initial onset of fog. This is the 0400 local time morning sounding. Prior to all fog sequences, the base of the inversion was moving down. Along with this, the thickness was increasing, while the thermal gradient was decreasing. Thus, the inversion was subsiding and weakening. A definitive warming, then cooling trend was not found in all of the summer cases.

2. Fall

Of the three seasons studied, fall had the greatest number of fog days and the greatest number of fog hours, 90% of which consisted of periods of fog in excess of two hours. This was also the season with the greatest amount of missing data, but indications are that fog occurrences are more likely after the 00GMT afternoon sounding than the earlier 12GMT morning sounding. Fog beginning between 0001GMT and 1159GMT extended through the 12GMT sounding in 61% of those type cases. Considering available data, there were only two cases, in late fall, where the fog was not preceded by an inversion. There were no cases where a sounding taken during fog did not show an inversion.

Analysis of the three inversion parameters, height of the inversion base, its thickness, and its temperature gradient, did not show any consistency. This was true for both the 00GMT and 12GMT soundings.

3. Winter

Winter statistics show a decrease in the amount of fog relative to the fall (86%). Again, most of this fog, 92%, occurs in duration periods in excess of two hours. A majority (78%) of the fog periods began after the afternoon 00GMT sounding with 78% of the cases extending through the 12GMT morning sounding. Only one case existed where the sounding immediately preceding the onset of fog did not contain an inversion. For soundings taken during fog, two cases out of the 13 did not contain an inversion. So, even in the winter, where the synoptic scale weather patterns consist predominantly of cyclonic systems and frontal passages, the inversion is still a congruent part of the fog picture.

The behavior of the 00GMT afternoon soundings reflect characteristics brought out by Leipper [7] in a 1968 paper. That is, there is a superadiabatic surface layer indicated by the sounding, in which the fog layer can grow. Above this, there is generally an inversion. In the 24-hour change of the 00GMT soundings preceding the fog, the height of the inversion base rose. Change characteristics of the inversion thickness and temperature gradient parameters were not constant. Changes in the soundings further back in time showed no consistency, and in some cases, inversions within them did not even exist.

It is the author's opinion that in the cases where inversions did not exist, but seemingly should have, there may have been an inversion near the sea surface. The site

where the radiosonde balloon is launched is located approximately five miles inland and at an elevation of 124 meters above sea level. This 124-meter layer could contain a shallow surface superadiabatic layer, and a shallow inversion.

The 24-hour change in the 12GMT morning sounding was not only consistent, but very similar to the summer scheme. Here, the base of the inversion remained at the surface. It should be noted that this surface inversion had been present for two previous 12GMT soundings as well. The last 24-hour change in the thickness was to deepen the inversion layer. At the same time, the inversion's temperature gradient decreased. The change in these last two parameters seemingly indicates weakening of the inversion. However, the soundings show that a very shallow surface layer retains a strong inversion, while the layer above this (still an inversion) increases in thickness.

A somewhat unusual pattern in the 24-hour 12GMT sounding changes, with regard to general and surface temperature changes, was found. The thermal changes preceding, during, and after a fog occurrence or sequence are tabulated in Table III in four stages.

TABLE III

TEMPERATURE CHANGES IN SOUNDINGS

Temperature Change	Stages				
	1	2	3	4.1	4.2
Atmosphere In General	W	W	K	NI	K
Surface Temperature	K	W	W	W	K

*W = Warming, K = Cooling
NI = No inversion below 850 mb

Stage 1: No fog.

Stage 2: Fog to begin after next 00Z sounding (unless already present).

Stage 3: a) Fog exists during the sounding. Surface inversion is strong.

b) Secondarily: Same as Stage 2.

Stage 4: No fog. Fog over.

4. Spring

Fog data were available only for the month of April. There were 29.4 hours of fog in seven days. Soundings, and their inversions, which were related to the early April fog occurrence reflected the winter characteristics previously mentioned. Insufficient data, however, prevents the delineation of results for the entire season.

TABLE IV

FOG DATA AT OAKLAND, CALIFORNIA

Mo./Yr.	Fog Days	% of Month	Fog Hours	+2 Hour* Fog Days	% of Month	+2 Hour** Fog Hours
Jul 73	2	6.5	2:35	0	0.0	0:00
Aug 73	7	22.6	21:53	5	16.1	18:43
Sep 73	9	30.0	30:00	4	13.3	23:40
Oct 73	6	19.4	34:58	6	19.4	34:23
Nov 73	14	46.7	48:46	7	23.3	39:46
Dec 73	21	67.7	188:53	16	51.6	181:52
Jan 74	12	38.7	42:12	7	22.6	35:50
Feb 74	7	25.0	17:39	1	3.6	11:55
Mar 74	8	25.8	34:22	5	16.1	32:18
Apr 74	5	16.7	21:40	2	6.7	15:30
TOTALS	91	29.9	442:58	53	17.4	393:57
Season		% of Season			% of Season	
Summer	18	19.6	54:28	9	9.8	41:23
Fall	42	45.7	272:37	29	31.5	256:01
Winter	27	30.0	94:13	13	14.4	80:03

* +2 Hour Fog Days: Days containing a fog period more than 2 hours in duration.

** +2 Hour Fog Hours: Total of fog periods greater than 2 hours in duration.

B. OAKLAND RESULTS

Maritime advection fog is a fog most likely to begin effecting a mid-latitude west coast shore station in the afternoon when the sea breeze is strongest, barring, of course, any synoptic scale disturbances. At this station, however, morning fog, beginning after the 12GMT sounding between 1201GMT and 2359GMT, was more predominant.

Fog data for Oakland is found in Table IV. The summer months, when maritime advection fog is usually more frequent, were the months with the least amount of fog. In fact, July, 1973, was virtually fog free; just 2.6 hours. A predominant type of fog occurring from November through February is radiation fog [8]. Also, this is the time of year when cyclonic systems with their fronts dominate the weather. More than half the fog occurring at Oakland during this study was during the months of November, December, and January. This implies that the greater amount of fog at this station was not the type under study.

Statistics for fog in general at this station show that 29.9% of the 304 days studied were fog days having a total of 442:58 hours of fog. Of this 88.9% occurred in periods of duration exceeding two hours. This longer duration fog was experienced on only 58% of the fog days, and on only 17.4% of all days studied. December was the foggiest month. 67.7% of the days were fog days, and there was a total of 188.9 hours of fog, 96% of which was accounted for in periods in excess of two hours. December had almost four times

as much fog as the next closest month, November. Therefore, December being considered a part of the fall season (see Glossary of Terms), fall was the season with the most fog.

1. Summer

Relatively little fog occurred at the Oakland, California station during this season. Only 19.6% of the days in the three-month period counted as fog days. With reference to the tabulated values, it can be seen that one-half of the fog days accounted for 76% of the fog, and this was during individual periods in excess of two hours.

Most of the summer fog days began in the morning, after the 12GMT (0400Local) sounding. In the smaller number of cases where fog began after the 00GMT (1600Local) sounding, all but one case had fog beginning just prior to the 12GMT sounding. The summer fog, then, is predominantly a problem during the morning hours, with dissipation usually by 1200 local.

The 24-hour change in the inversion parameters of the last two 00GMT soundings prior to the beginning of a fog period or sequence indicates that the inversion becomes stronger. That is, the thickness decreases, and the temperature gradient increases. The movement of the inversion base does not follow any specific pattern throughout the entire season. For the month of September, however, a general warming trend is ended just prior to the fog occurrence with a cooling of the surface layer.

For the 24-hour change in the 12GMT morning sounding prior to fog, the parameters indicative of inversion strength did not show consistency. The last 24-hour change in height of the base of the inversion did exhibit a downward or subsiding movement. For the months of July and August, there was a general warming trend and apparent lowering of the inversion for two to three days prior to the fog. Apparent lowering means that the movement is downward (toward higher pressure) in relation to the pressure (mb) scale; the vertical change in relation to sea-level may be different. The 12GMT sounding of the day prior to fog shows cooling of the surface layer. Fog appears the next day, after the 12GMT sounding.

2. Fall

There were 42 fog days this season for a percentage of 45.7 of the three-month season. There were 272.6 hours, 69.3% of which occurred in December, late fall. Of the total hours, 93.9% were accounted for in periods whose duration exceeded two hours. In each month, the greatest portion of the total hours was found in these longer periods. October, in fact, had only one short-duration fog period.

Analysis of this season was made difficult by the large amount of missing data, especially in December. Of the 58 soundings directly associated with the fog incidences, 25 were missing (43%). The available data, however, indicate about the same number of fog periods beginning after the 00GMT afternoon sounding as after the 12GMT morning sounding.

In both categories, there ware two instances where the sounding preceding the fog did not contain an inversion. Three of the eleven available soundings taken during fog indicated no inversion present. So, the greater majority of available soundings taken just prior to, or during, fog include an inversion. See Figures 5, 6, 7, and 8 in Appendix A. Surface inversions dominated the 12GMT category taken prior to the occurrence of fog. In the three cases without surface inversions, the surface-1000mb layer was virtually isothermal; the temperature change being less than 0.5°C. The 12GMT surface inversion present prior to fog had been there for at least the last two soundings. Usually a surface inversion had been present for the last three soundings. The thickness and temperature gradient parameters did not have consistent change characteristics. The change in the general thermal structure and surface temperature of the 12GMT soundings on a 24-hour basis was not uniform at all. It is hypothesized then that the warning-then-cooling trend that would be associated with the build-up and condensation into fog of the moisture, takes place on a smaller time scale than this interval.

None of the three inversion parameters of the 00GMT afternoon sounding was found to be uniform in change prior to the onset of fog. The thermal tendency of the 00GMT soundings in general, for the month of October was found similar to that in September. With the exception of one fog day on the 28th of October, the soundings indicated a

warming trend of at least 24-hours followed by cooling of at least the surface layer, if not the whole sounding below 850 mb just prior to the beginning of fog. For November and December no such discernible pattern developed.

3. Winter

The winter season had a moderate amount of fog with 30% of the days characterized as fog days. Less than half of these days contained 85% of the fog in terms of hours. This 85% also represented fog periods which exceeded two hours. January contained the most fog of the three months, February the least; so, there was no continuous decline with the approach of spring.

Here, as in summer, the statistics show that the cases where fog began after the morning 12GMT sounding represent the majority. However, there is a difference in that there are several instances of late morning-early afternoon fog during this season. So, actually, there was no one part of the day where fog formation, or occurrence at the station, generally began.

Of the last soundings taken prior to the onset of fog, 78.3% contained inversions. This was true of 87.5% of the afternoon 00GMT soundings, and 73.3% of available morning 12GMT soundings. The presence of fog during a sounding did not imply the presence of an inversion. Only 62.5% of these soundings included an inversion. See Figures 5, 6, 7, and 8 in Appendix A.

Winter inversions are characterized by Rosenthal [12] as being generally weak. It was found in this study that the 24-hour change in an inversion prior to the onset of fog, was to weaken it in most cases. That is, the thickness decreased, and the temperature gradient also became of lesser magnitude. This was for both 00GMT and 12GMT soundings. The base of the inversion during 12GMT sounding changes exhibited consistency during the months of January and February. When there was an inversion present, it was a surface inversion, and had been present for two to three soundings as a rule. March did not reflect this characteristic.

Day to day changes in the thermal characteristic of soundings did not have a particular pattern. It is suspected that the numerous frontal passages, associated with this season, mask any pattern that might solely be ascribed to marine advection fog.

4. Spring

Fog data were available only for the month of April. There were 21.7 hours of fog in five days. No discernible pattern in sounding behavior or inversion characteristics presented itself. Insufficient data restricts the delineation of any results for this season.

C. QUILLAYUTE/SEA-TAC RESULTS

The third geographical area tasked for consideration in this project was in the state of Washington. The upper air soundings used here were taken at Quillayute, Washington,

on the Pacific Coast of the Olympic Peninsula. Approximately 100 miles inland, to the east of 7965-foot Mount Olympus, between Puget Sound and Lake Washington, is located the Seattle-Tacoma Airport (SEA-TAC) where the hourly observations were taken.

Advection fog in the observation area has three sources. Two are from Lake Washington to the east, and one is from the Pacific Ocean. This latter is the rarest of the three. Maritime advection fog flows from the Pacific Ocean through the break in the coastal range in the vicinity of Hoquiam, Washington [11]. Hoquiam is located about 70 miles south of Quillayute and 90 miles southwest of the Seattle-Tacoma Airport. So the marine advection fog must travel approximately 100 miles over land to reach our surface observation point; and, originate in an area some 70 miles to the south of theupper air sampling sight.

Due to all of the above mentioned factors, a relationship between fog observed at SEA-TAC, and the upper air soundings taken at Quillayute was considered most unlikely for purposes of this study. Subsequent attempts at analysis bore this out. All data at these two stations have been organized and statistized, but will not be pursued further here.

V. CONCLUSIONS

Marine advection fog was the subject fog for this thesis. Finding a relationship between it and temperature inversions was the object. If a relationship could be established with this small data base, then the follow-on project would be to check it with a broader data base by computer, and expand the number of parameters investigated.

In relation to the background material, results tend to support Leipper's findings for San Diego. Also, an interesting contrast to Rosenthal's work on inversions was found. He found inversions to be lower and stronger in the summer, higher and weaker in the winter. In this study, inversions related to fog were found to be lower in the winter. In fact, 12GMT inversions were surface based. The inversions alone were not the object of this study, but the shallow surface portion of the winter 12GMT inversions related to fog were found to be quite intense. The remaining portion above this, however, was very weak, and served to give a deceptive picture of the inversion's overall strength.

There is a point to be kept in mind as regards the type of fog. The hourly observations do not differentiate as to the type of fog reported. Marine advection fog is only one of several types occurring during the fall and winter seasons when the weather is much more active. The stability of the weather during the summer lends itself to the

likelihood that fog beginning just before or after the 00GMT sounding is marine advection fog. This due to the fact the sea breeze is strongest in the afternoon, thus, the marine advection fog has the greatest chance of being blown into the coastal stations.

Another point to be kept in mind while considering the conclusions drawn from the data is the location of the stations. The San Diego stations are located reasonably near the open ocean. The Oakland stations are not located adjacent to the open ocean, but inland from the Pacific Coast on the east side of the San Francisco Bay. Marine advection fog must enter the bay to the north of the Oakland station, then come south. Prevailing afternoon winds during the summer would make this quite possible [8].

A summary of conclusions drawn from the results of San Diego and Oakland follows; examples as applicable are illustrated in the Figures contained in Appendix B.

1. Summer fog cases are preceded by an inversion in the atmosphere below 850 mb.
2. Fall and winter fog cases are preceded by an inversion in the majority of occurrences. Considering only the soundings that were available, this was 92% for San Diego and 80% for Oakland. In San Diego, the exceptions were limited to November through January.
3. For the situation of soundings taken during fog, the lack of an inversion below 850 mb is the

exception rather than the rule. This is especially true in the summer and early fall.

SAN DIEGO

4. With the exception of the height of the inversion base during the winter season, only the last 24-hour change (in the inversion parameters) before the initial onset of fog reflects any absolute consistency or pattern.

5. Summer: The thickness of the 00GMT inversion layer will decrease in the last 24-hour change prior to the occurrence of fog. The last 24-hour change in the 12GMT morning sounding has the inversion layer weakening, i.e. increasing in thickness while the temperature gradient decreases. For both soundings the inversion base is moving downward. Where fog is to persist, there is a general warming trend in the lower atmosphere associated with a subsiding inversion in the 00GMT sounding. The fog is preceded by cooling of the surface layer.

6. Fall soundings and their inversions displayed no pre-fog consistency.

7. Winter: The base of the inversion in the last 24-hour change of the 00GMT afternoon soundings rises before a fog occurrence or sequence. The base of the inversion in the 12GMT morning sounding is at the surface for at least four soundings prior to fog. In the last 24-hour period before fog begins the

strength of the inversion layer lessens. The depth increases while the temperature gradient decreases. This is reflected largely in that part of the inversion above the shallow surface portion which retains considerable intensity.

OAKLAND

8. 24-hour changes in inversion thickness and temperature gradients further back in time than the last 24-hour change do not show consistency.

9. Summer: The inversion layer becomes stronger during the last 24-hour change in the afternoon 00GMT sounding (below 850 mb) prior to a fog occurrence or sequence. That is, the thickness decreases and the temperature gradient increases. Consistency in the last 24-hour change, in the inversion of the 12GMT morning sounding, prior to fog is limited to the height of the inversion base decreasing. During the months of July and August this is accompanied by a two- to three-day warming trend, with cooling of the surface layer the day before fog. Fog is likely the next day after 1200GMT (0400Local).

10. Fall: There is almost always a surface inversion in the 12GMT morning soundings prior to the onset of fog. This surface inversion is present for at least two 12GMT soundings; and where the base is higher, the layer below 1000 mb is virtually isothermal.

11. The months of September and October have similar thermal tendencies prior to fog in the 00GMT soundings below 850 mb. At least a 24-hour warming trend is followed by cooling of at least the surface layer.

12. Winter: As previously noted, inversions do not always accompany or precede fog. Also, no one part of the day is significantly more common relative to the observance of fog. Considering the weather of this season, the implication is that marine advection fog is not a dominate type during the winter.

13. Winter: Generally, the 24-hour change in an inversion prior to fog is in the form of weakening or, dissipation toward an isothermal state, of that inversion. This is true for the 24-hour changes in both the 00GMT and 12GMT soundings. The thickness decreases as does the temperature gradient of the inversion layer.

14. For January and February, inversions in the 12GMT soundings prior to the onset of fog are surface inversions. They are present for two to three pre-fog soundings.

QUILLAYUTE/SEA-TAC

For reasons delineated in the results section, conclusions were not undertaken for these stations. Since commencement of this project, it has been found that hourly surface observations are available from the Quillayute station, as well as the upper-air soundings. These should be used in the follow-on study.

VI. RECOMMENDATIONS

A much broader data base, five years for example, would give a better and longer look at the individual seasons, and would also smooth out the effects of any unusual seasons or years. Such a study would require the use of a computer in parameter analysis. Hand methods used in this thesis would take much too long.

It would be most desirable for the upper-air sounding station and surface observation station to be at the same location. Thus, the local meteorological effects at the station where fog is observed will be better reflected by the radiosonde sounding.

Exactly what type of fog is observed is not recorded in the hourly surface observation log. Marine advection fog is most likely to begin being observed in the afternoon, since the sea breeze is usually strongest then, and is more likely to advect the fog ashore. A study of fogs beginning only in the afternoon, after 2230GMT (1430Local) for example, would increase the likelihood of the fog type being marine advection fog.

GLOSSARY OF TERMS

Apparent height:	Refers to height relative to the pressure scale in the atmosphere. Apparent height increases with decreasing pressure.
Fall season:	The months of October, November, and December. These three months best represent the period between the autumnal equinox, September 21, and the winter solstice, December 21.
Fog:	Includes both ground fog and fog categories used in United States weather observing practice, the difference between them being that ground fog hides less than 0.6 of the sky.
Fog day:	A day between 0000Z and 2359Z which contains fog.
Fog sequence:	Two or more consecutive fog days.
Inversion layer:	Temperature inversion layer. For purposes here, this includes isothermal layers as well as atmospheric layers where temperature increases with height.
Spring season:	The months of April, May, and June. These three months best represent the period between the vernal equinox, March 21, and the summer solstice, June 21.

Summer season:	The months of July, August, and September. These three months best represent the period between the summer solstice, June 21, and the autumnal equinox, September 21.
Winter season:	The months of January, February, and March. These three months best represent the period between the winter solstice, December 21, and the vernal equinox, March 21.

APPENDIX A

DATA GRAPHS: INVERSION OCCURRENCE RELATIVE TO FOG DAYS

Bar graphs are used to display this data rather than tables of numbers, the idea being that visualization is easier. In general, the first bar in each group represents the actual number of fog days as specified by "A" in the legend. The second bar represents the number of cases in the first bar where the upper-air radiosonde sounding during, or just prior (00Z or 12Z as designated) to, fog, contained an inversion below 850 mb. Note that "Z" (zulu) and GMT mean the same thing. Also shown in this bar are the number of inversions that were surface inversions. The third bar represents the number of soundings, referred to in the second bar, that did not contain inversions below 850 mb. Bar number four represents the number of soundings taken during, or just prior (as designated) to, a fog occurrence. Note that the total of bars two, three, and four equal the first bar.

There are four groups of two charts for each station, i.e. San Diego and Oakland. Each group displays the data by month, season, and a 10-month total. The legends are the same for both charts in a group. It should be emphasized that these charts are intended only to show data, and not be a statistical display of any form.

The results derived from this data are discussed in the appropriate results section. It can be quickly seen in

these bar graphs, though, that fog occurring without an associated temperature inversion below 850 mb is the exception rather than the rule. Where no such inversion is indicated, there may in fact be one over the water adjacent to the station in the case of Oakland. If the air is warmer than the water, at least a very shallow inversion layer will exist. In the case of San Diego, the elevation of the upper-air sounding station does not allow a temperature inversion layer existing below 124 meters to be picked up by the radiosonde.

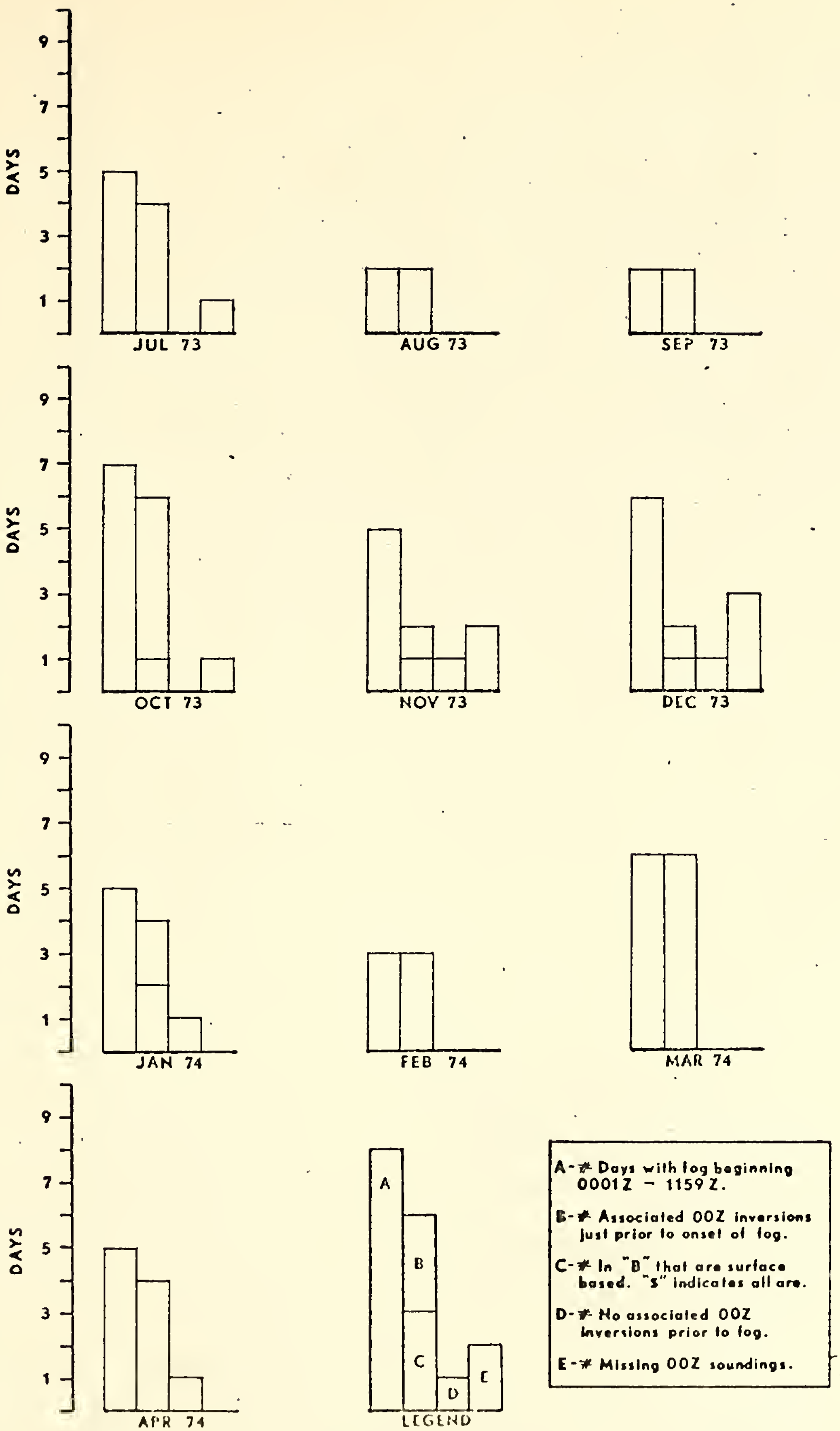

Figure 1a. San Diego. Fog beginning between 00GMT and 12GMT.

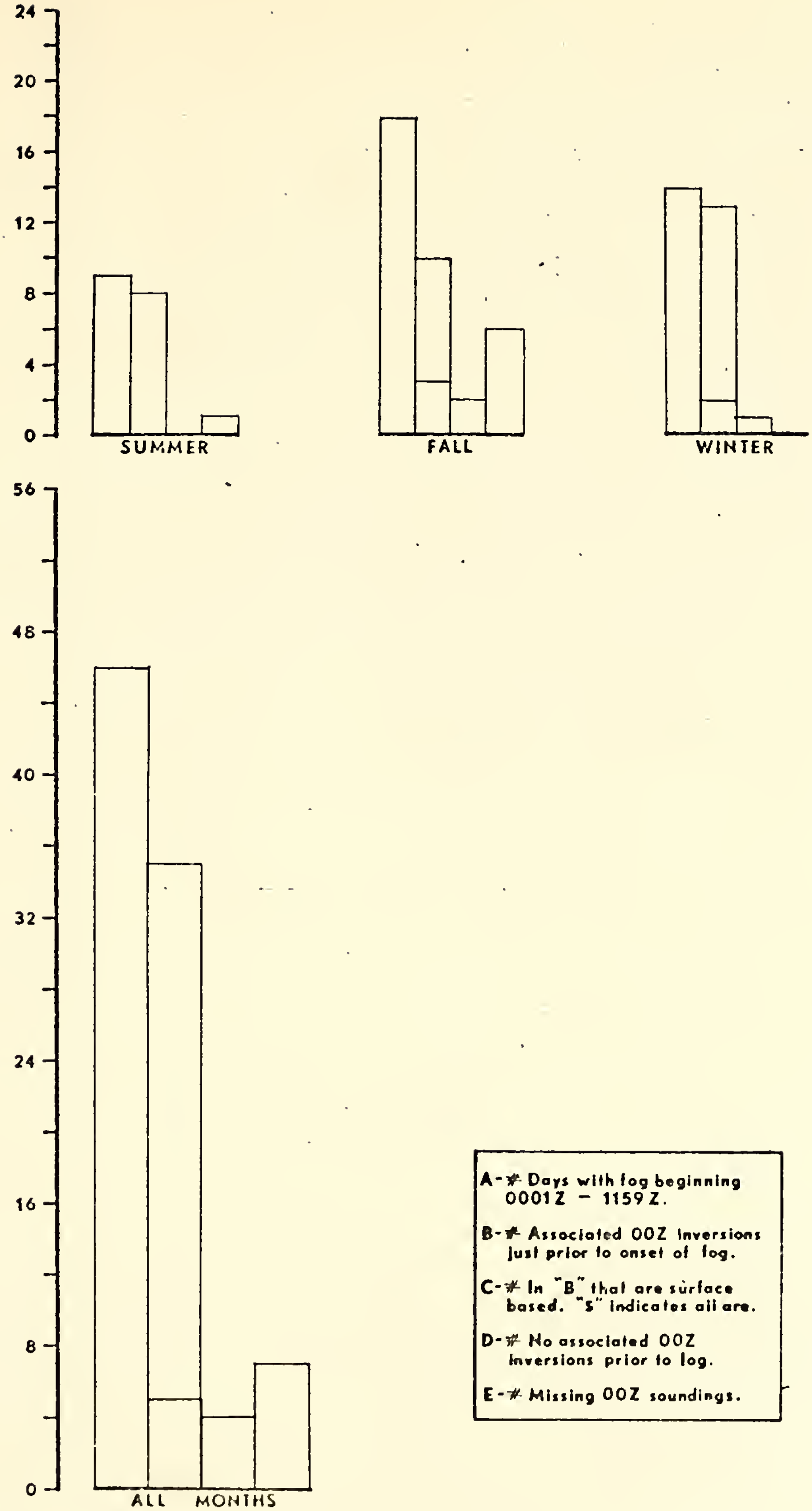

Figure 1b. San Diego. Fog beginning between 00GMT and 12GMT.

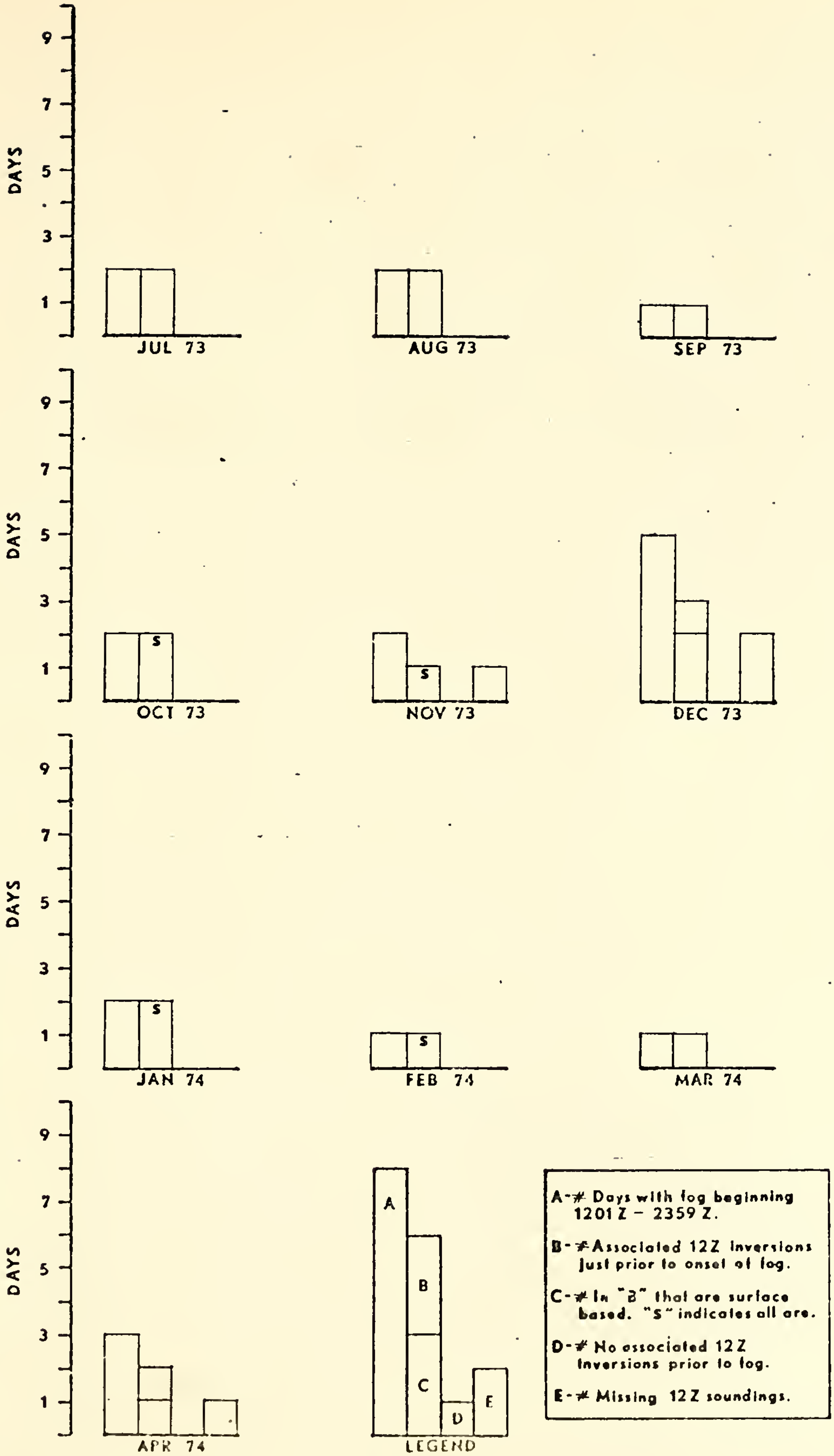

Figure 2a. San Diego. Fog beginning between 12GMT and 00GMT.

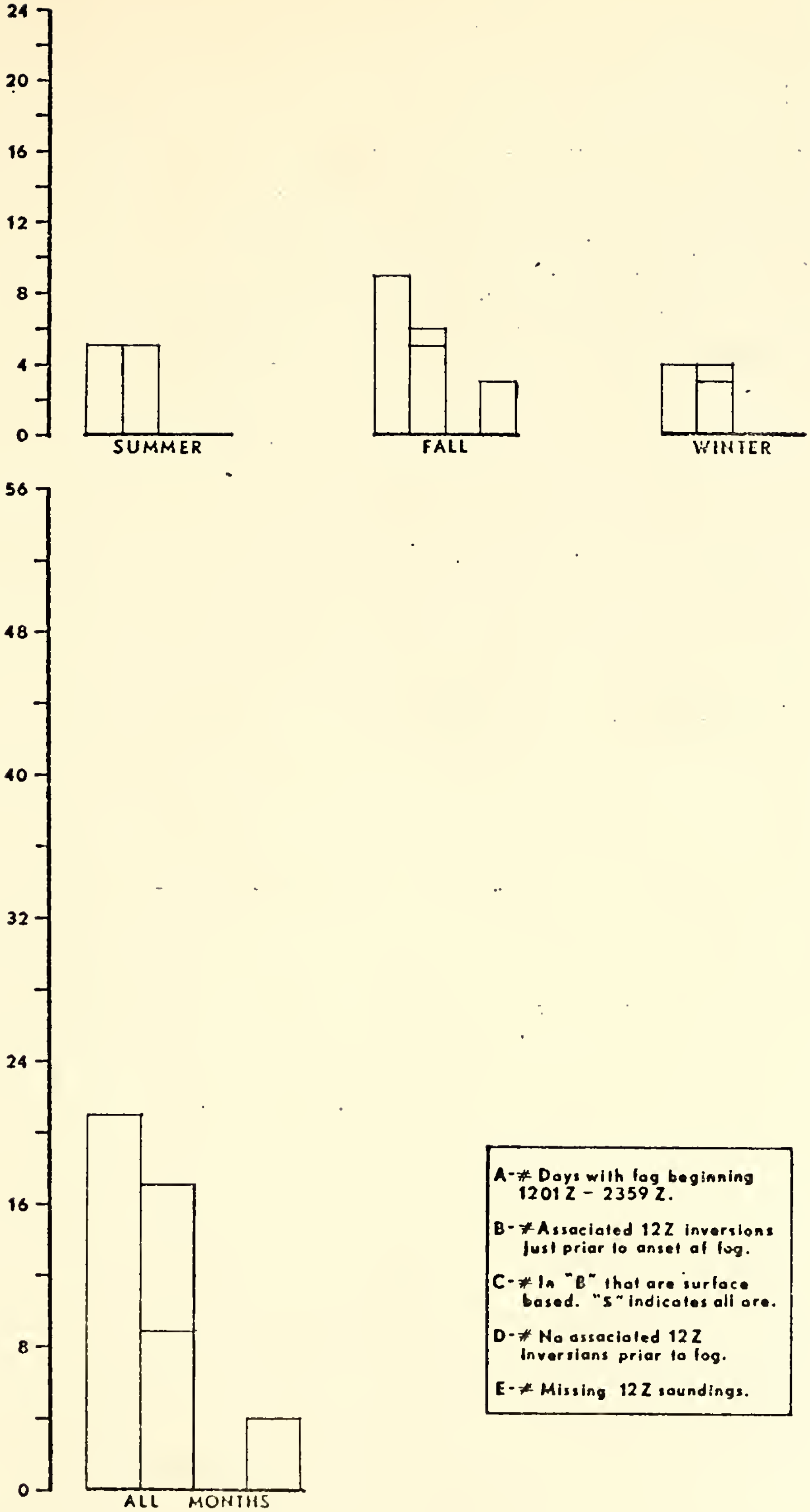

Figure 2b. San Diego. Fog beginning between 12GMT and 00GMT.

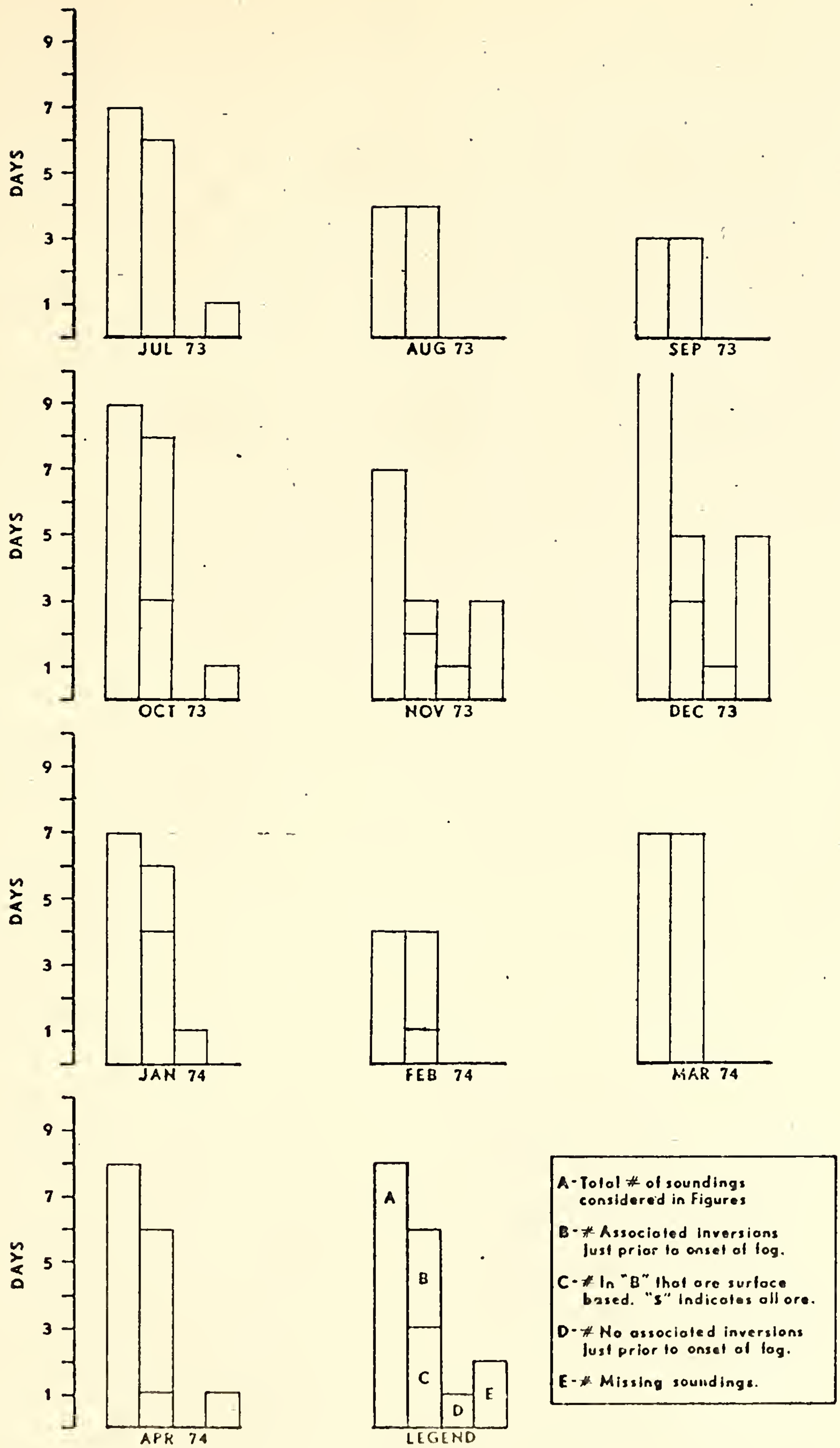

Figure 3a. San Diego. Summation of Figures 1a and 2a.

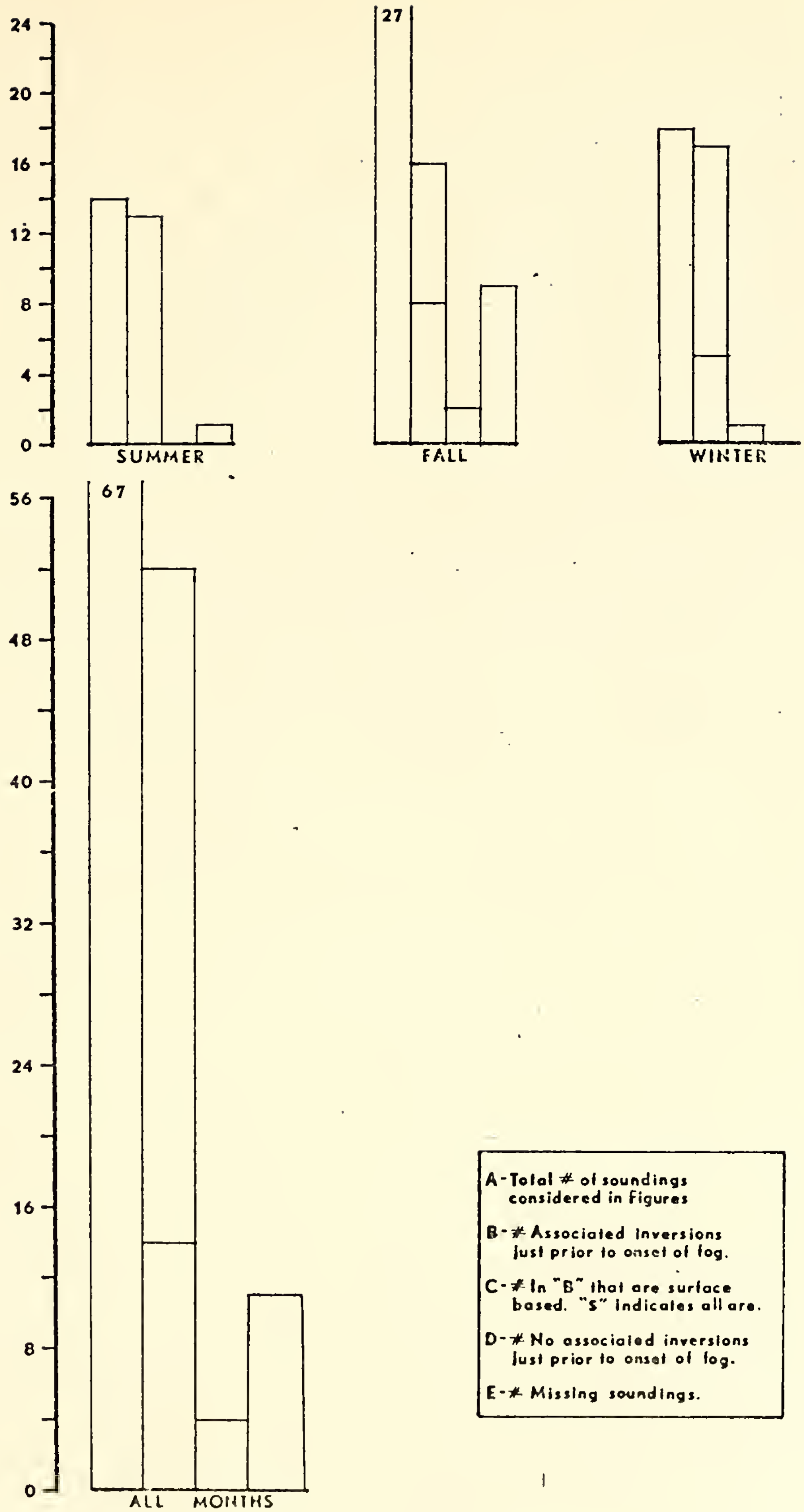

Figure 3b. San Diego. Summation of Figures 1b and 2b.

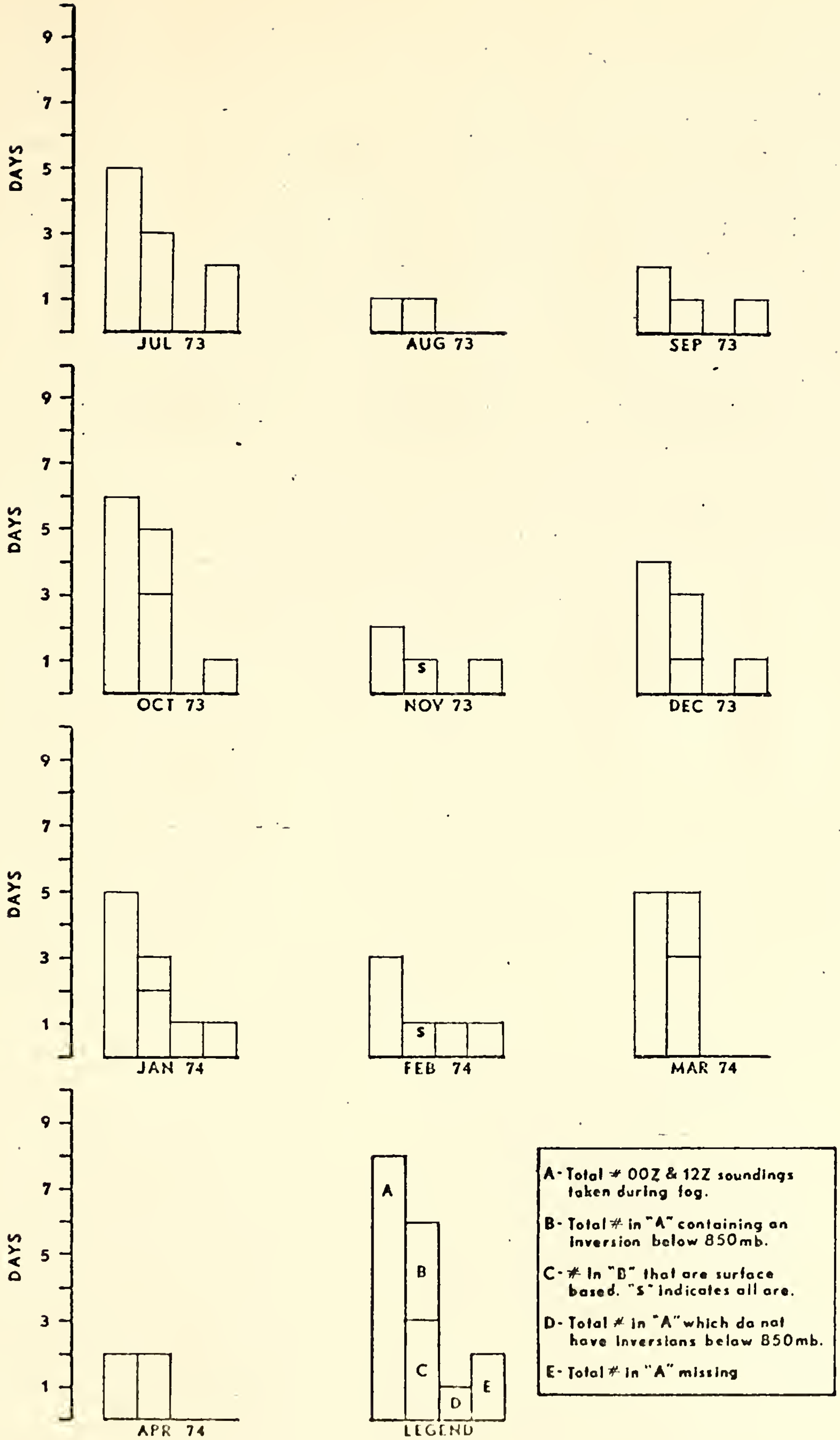

Figure 4a. San Diego. Soundings taken during fog.

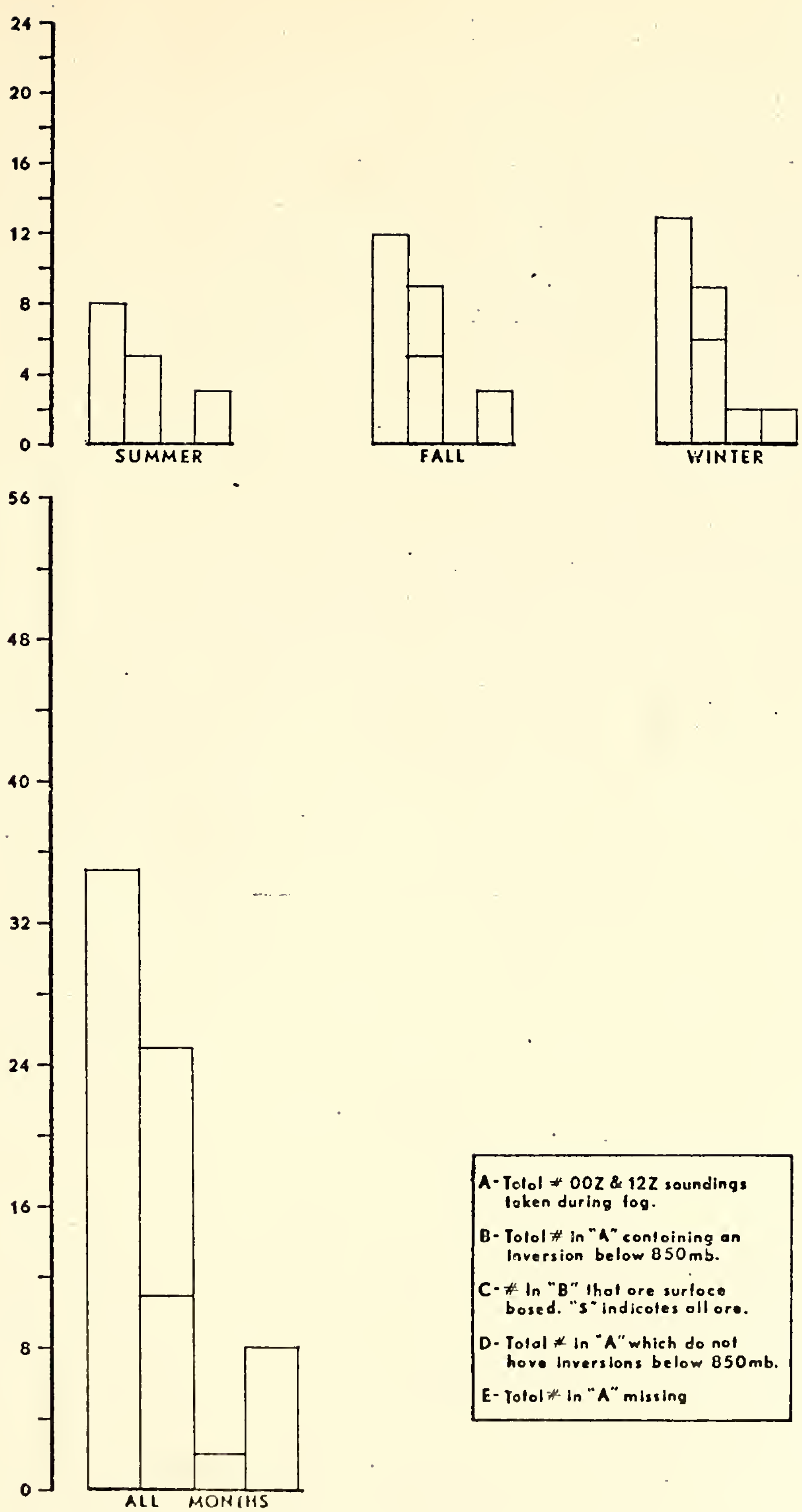

Figure 4b. San Diego. Soundings taken during fog.

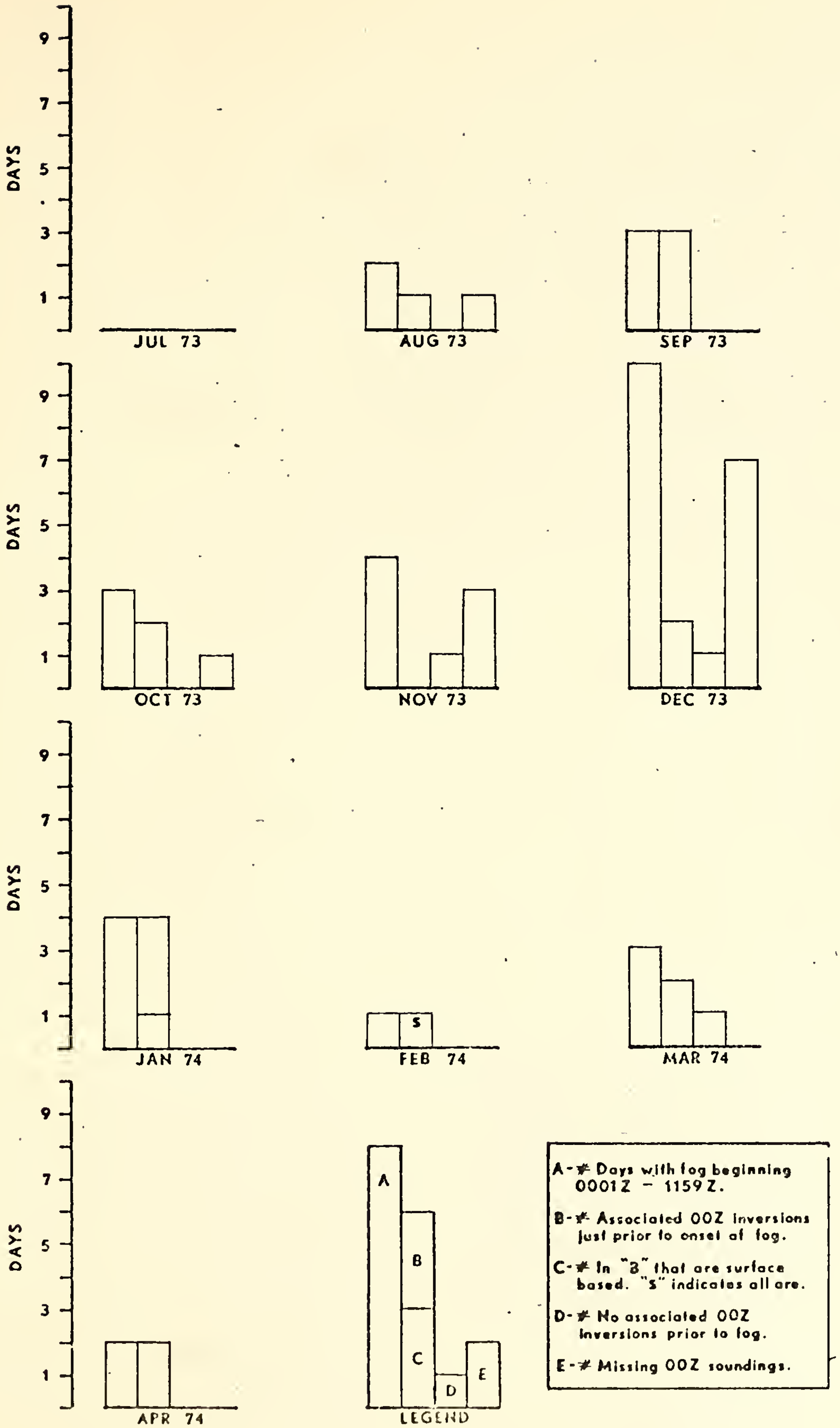

Figure 5a. Oakland. Fog beginning between 00GMT and 12GMT.

Figure 5b. Oakland. Fog beginning between 00GMT and 12GMT.

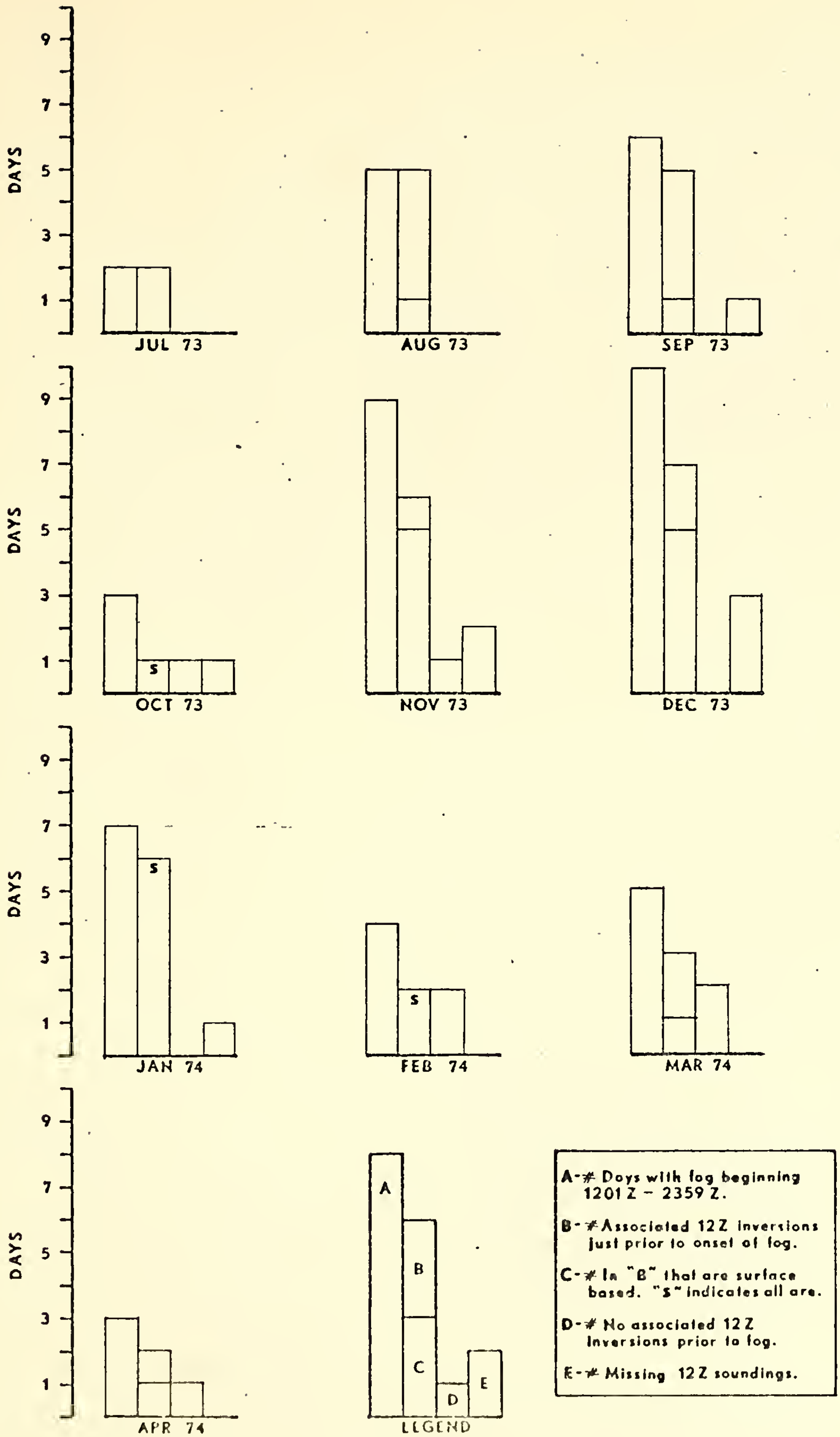

Figure 6a. Oakland. Fog beginning between 12GMT and 00GMT.

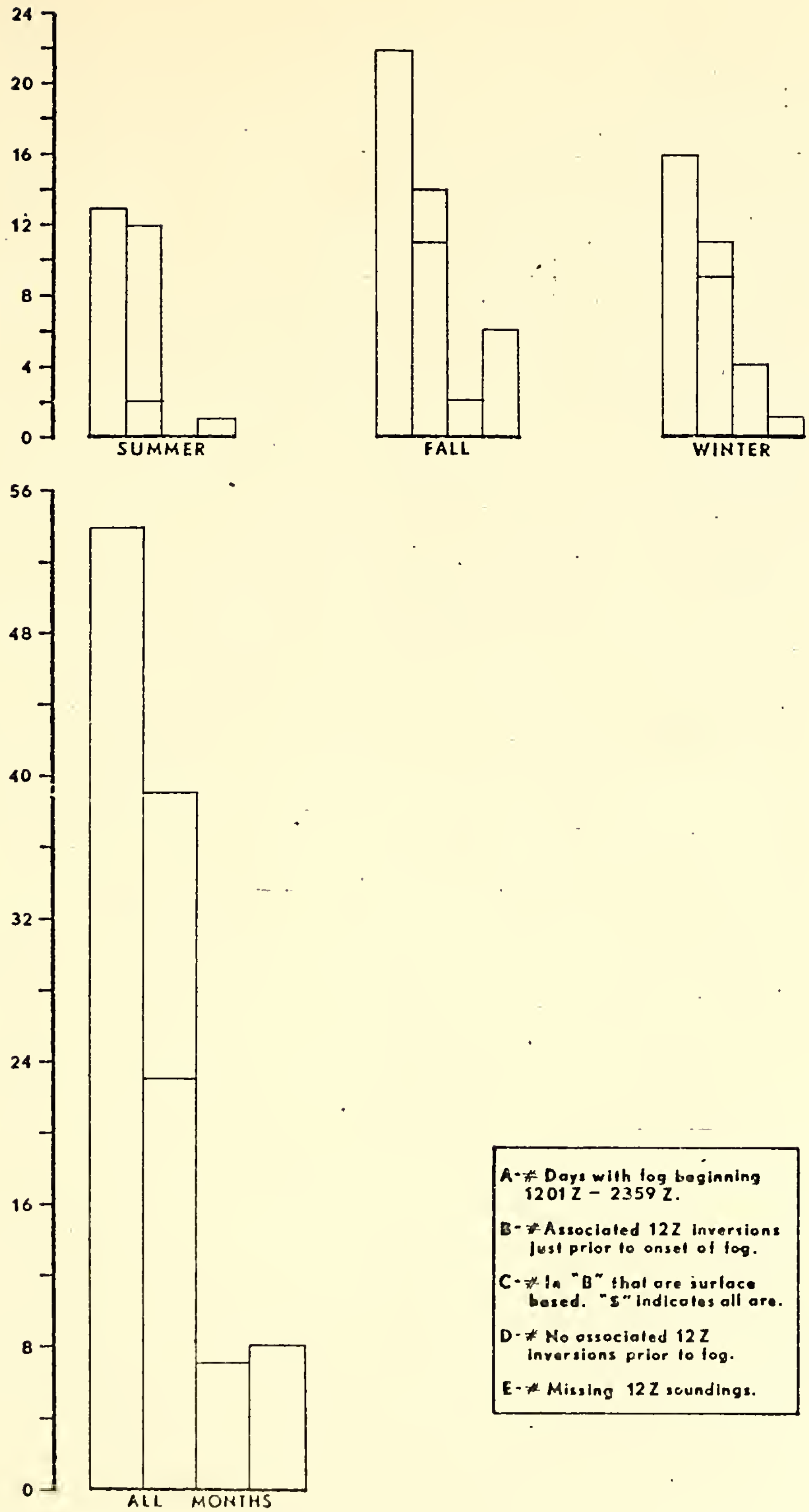

Figure 6b. Oakland. Fog beginning between 12GMT and 00GMT.

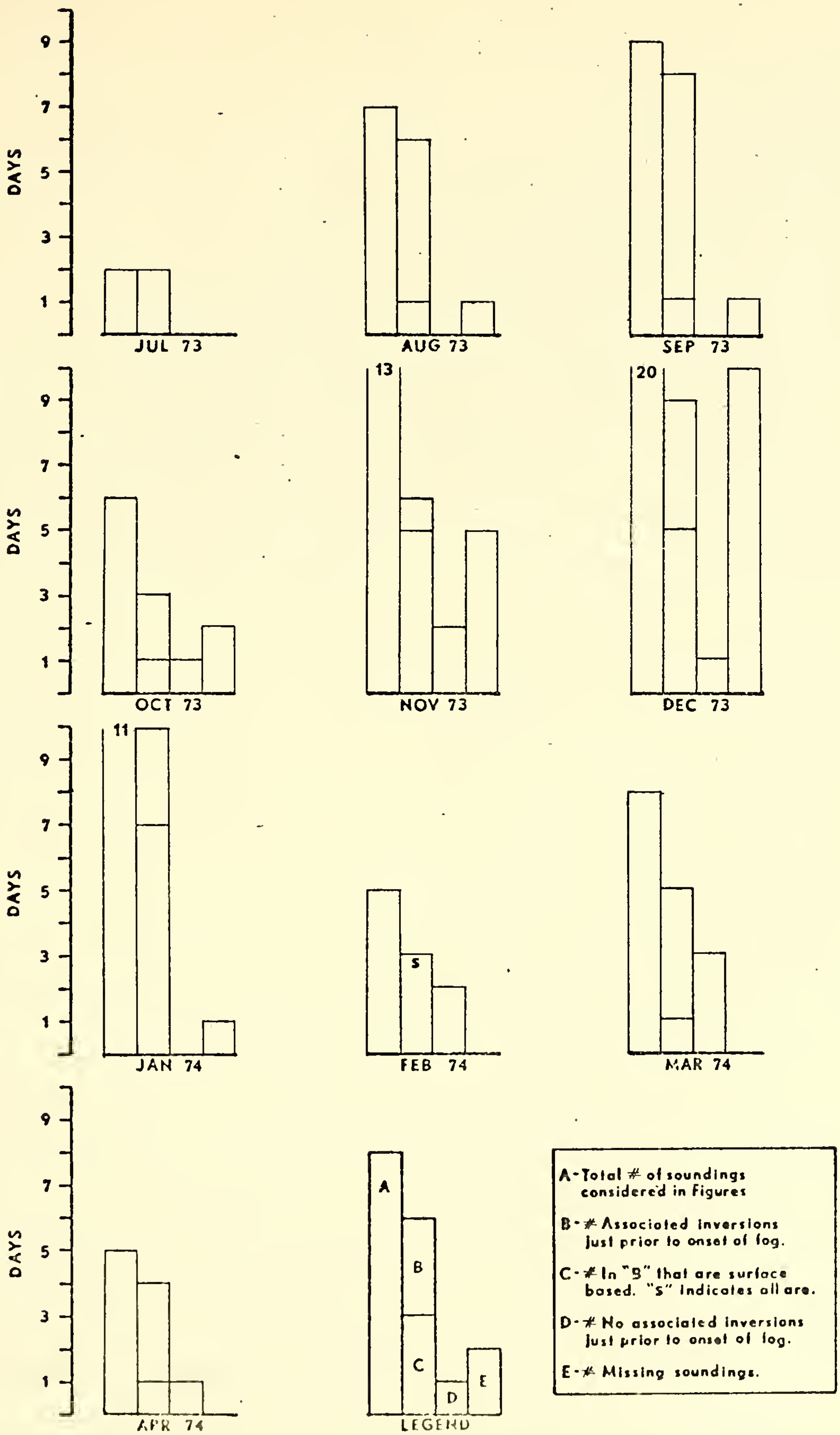

Figure 7a. Oakland. Summation of Figures 5a and 6a.

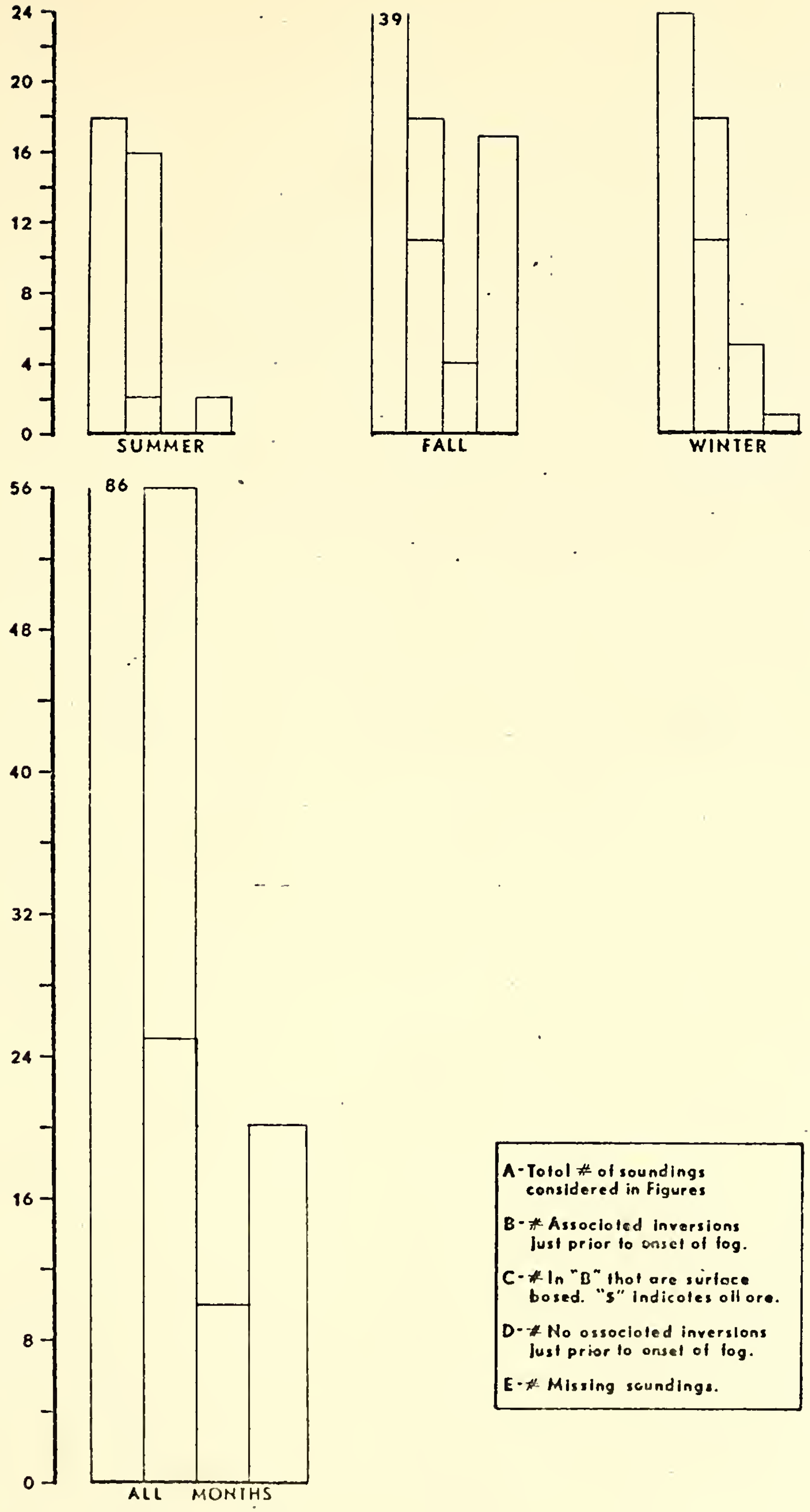

Figure 7b. Oakland. Summation of Figures 5b and 6b.

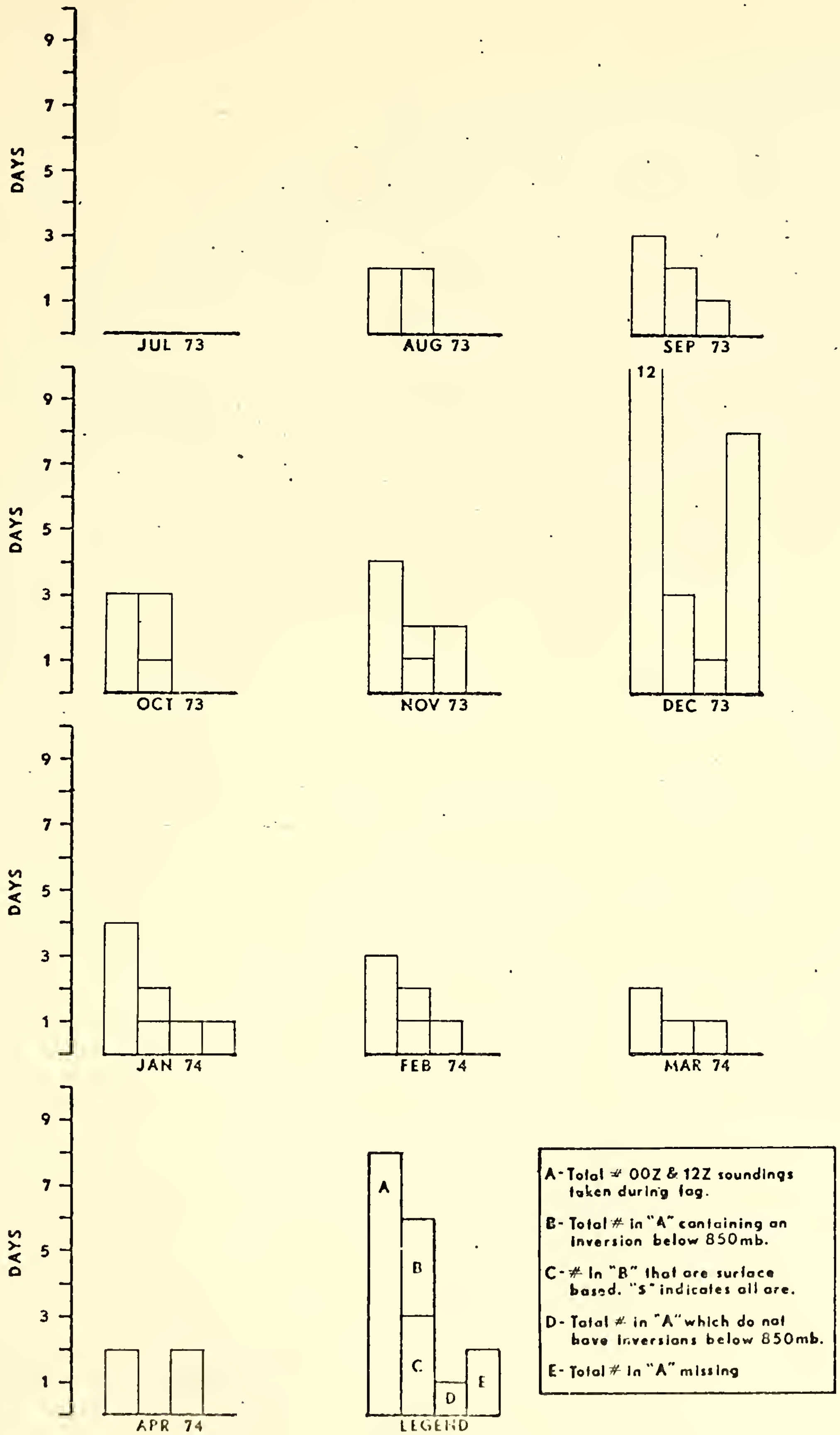

Figure 8a. Oakland. Soundings during fog.

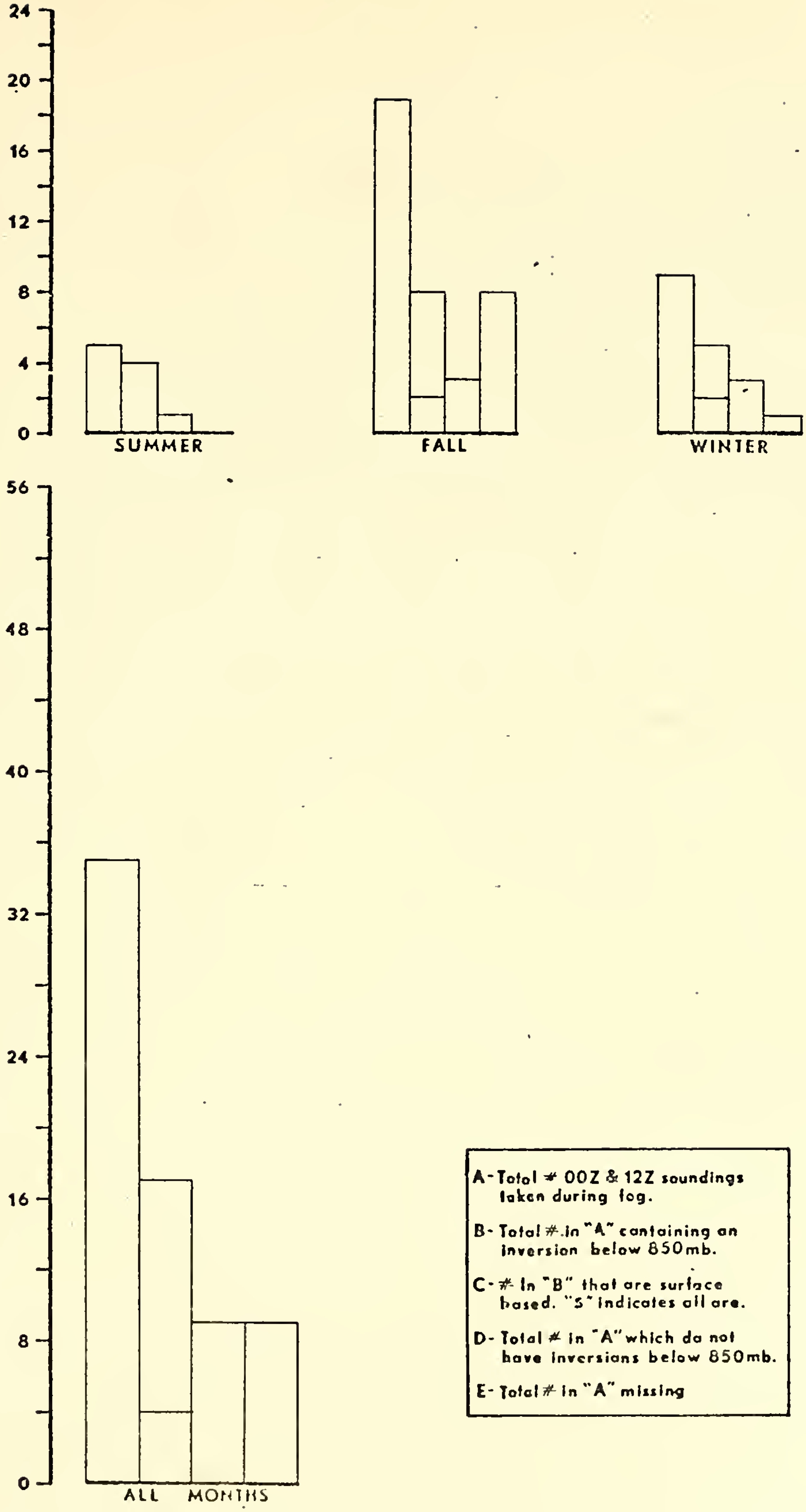

Figure 8b. Oakland. Soundings during fog.

APPENDIX B

FOG CASE EXAMPLES

There are four examples given here that reflect the changes in the temperature inversion parameters and sounding thermal changes, below 850 mb, as discussed in the thesis results and conclusions. Example situations are from the summer and winter seasons, for the San Diego and Oakland stations.

Graphs displaying the 24-hour changes in the height of the inversion base, the thickness of the inversion layer, and the temperature gradient within the inversion layer are shown for both the 0000Z and 1200Z soundings. (Time Z is the same as GMT.) Absissa numbers are dates in the given month. General 24-hour changes in these soundings can be seen in the accompanying figures that show them for the series of days used as a fog case. Shaded areas indicate a 24-hour change to warmer temperatures, unshaded, to cooler temperatures.

Case I. San Diego. Summer.

A. Fog occurrences:

4 July 1973; 0940Z to 1803Z; 8 hours 23 minutes
(0140L to 1003L)

5 July 1973; 1140Z to 1730Z; 5 hours 50 minutes
(0340L to 0930L)

6 July 1973; 1225Z to 1515Z; 2 hours 50 minutes
(0425L to 0715L)
1710Z to 1810Z; 1 hour
(0510L to 1010L)

10 July 1973; 1335Z to 1726Z; 3 hours 51 minutes
(0535L to 0926L)

B. Discussion for parameter changes found to be consistent:

The graphs for the 00Z inversion parameters show the thickness decreasing and base lowering in the last 24 hours (3rd to 4th) prior to the beginning of the fog sequence (4th through 6th), and prior (9th to 10th) to the fog occurrence on the 10th. The 00Z sounding figures show general warming the 1st through the 3rd, with the surface layer cooling 3rd to 4th.

Graphs for 12Z inversion parameters show the inversion layer weakening in the last 24-hour change prior to the onset of both the fog sequence and singular fog occurrence. The inversion base is moving down as in the 00Z soundings. Figures 12 show the day-to-day warming prior to the fog sequence and cooling each day during. The change from the 6th to the 7th also shows cooling, but the inversion is intensifying significantly.

12Z factors indicate that fog would probably occur on the 9th. It did not, but the lowest ceiling of the day (152 m) occurred shortly after the 12Z sounding on the 9th.

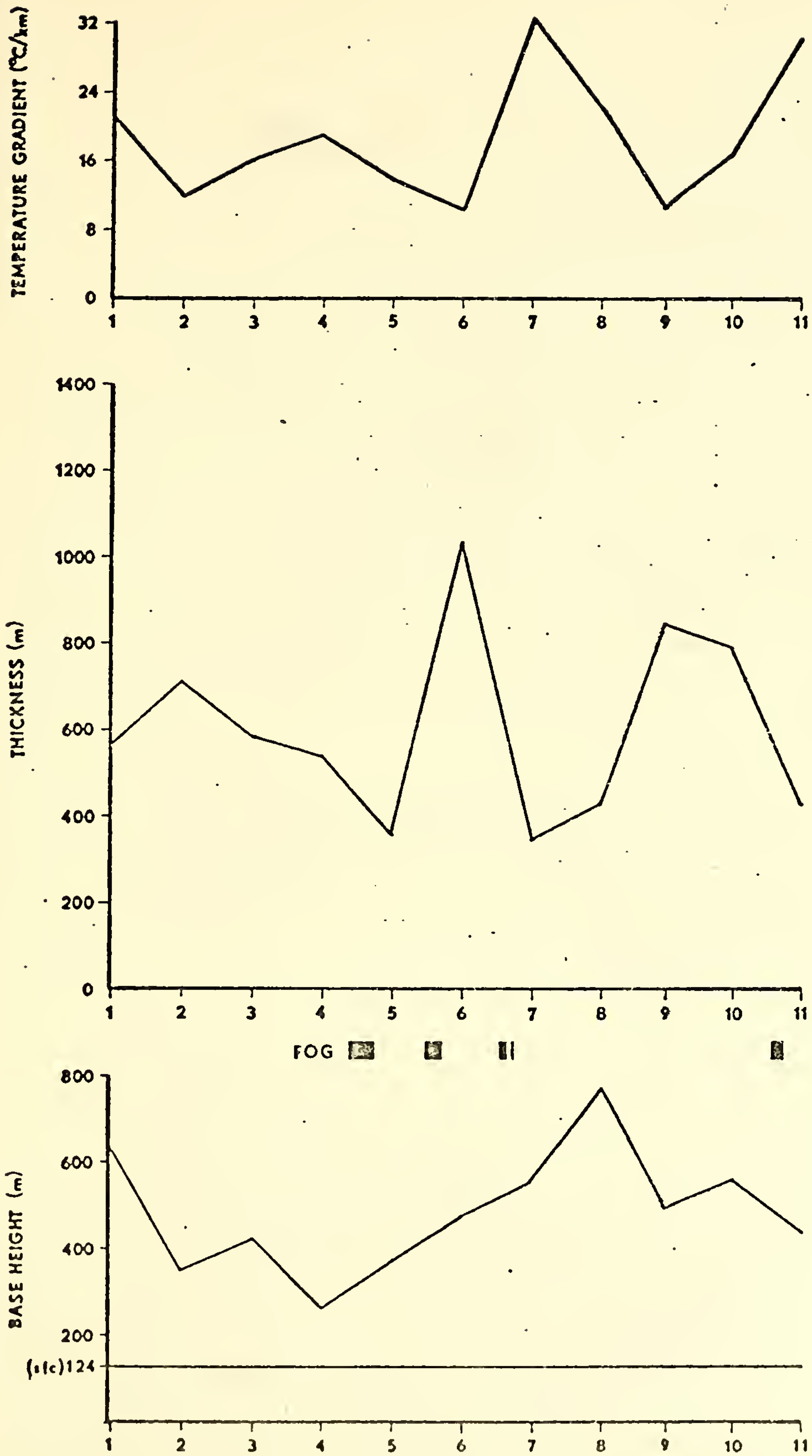

Figure 9. San Diego. Inversion Parameters. July 1973. 00GMT.

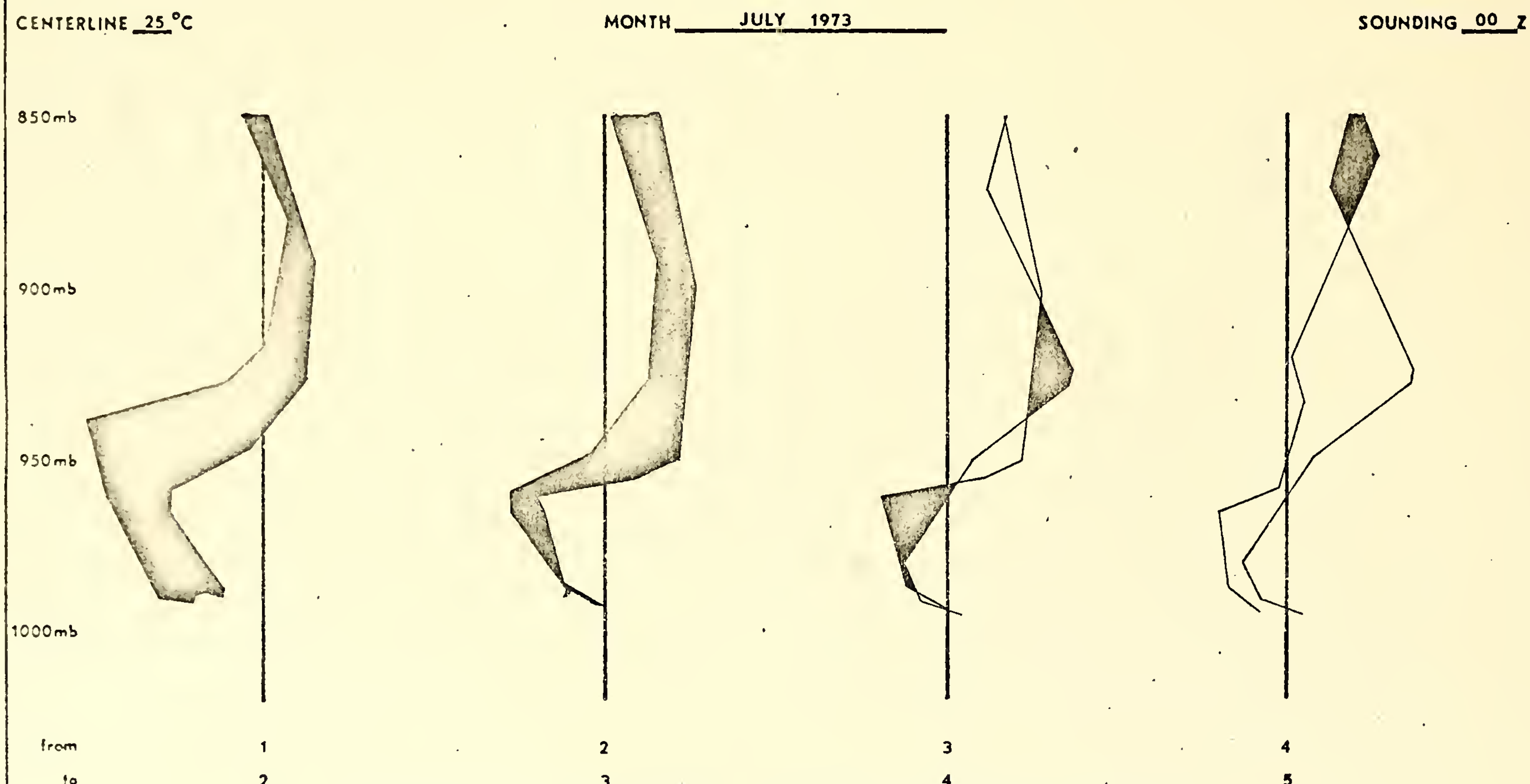

Figure 10a. San Diego. 24-hour sounding changes.
Shaded areas indicate change to warmer temperatures.

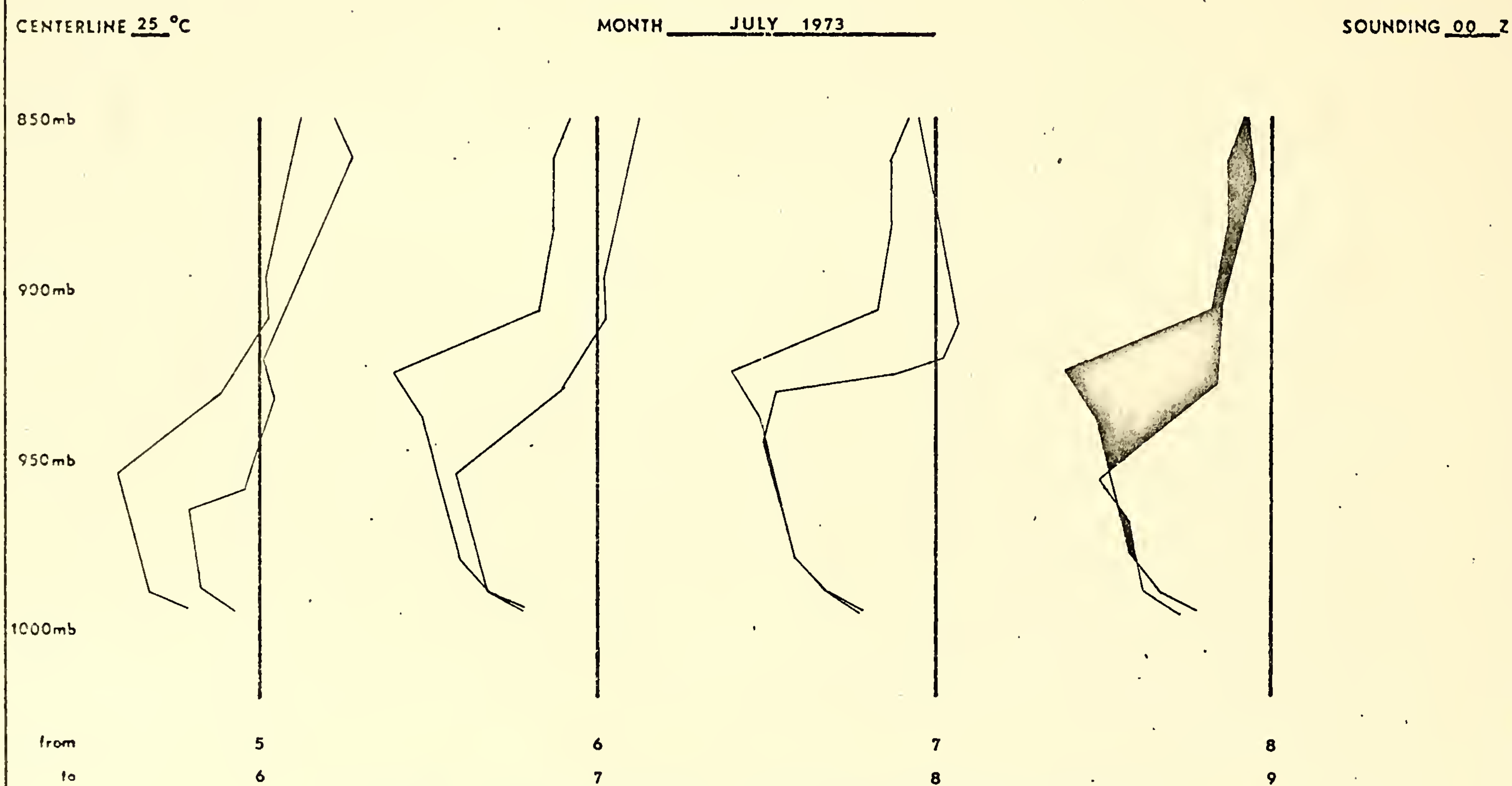

Figure 10b. San Diego. 24-hour sounding changes.
Shaded areas indicate change to warmer temperatures.

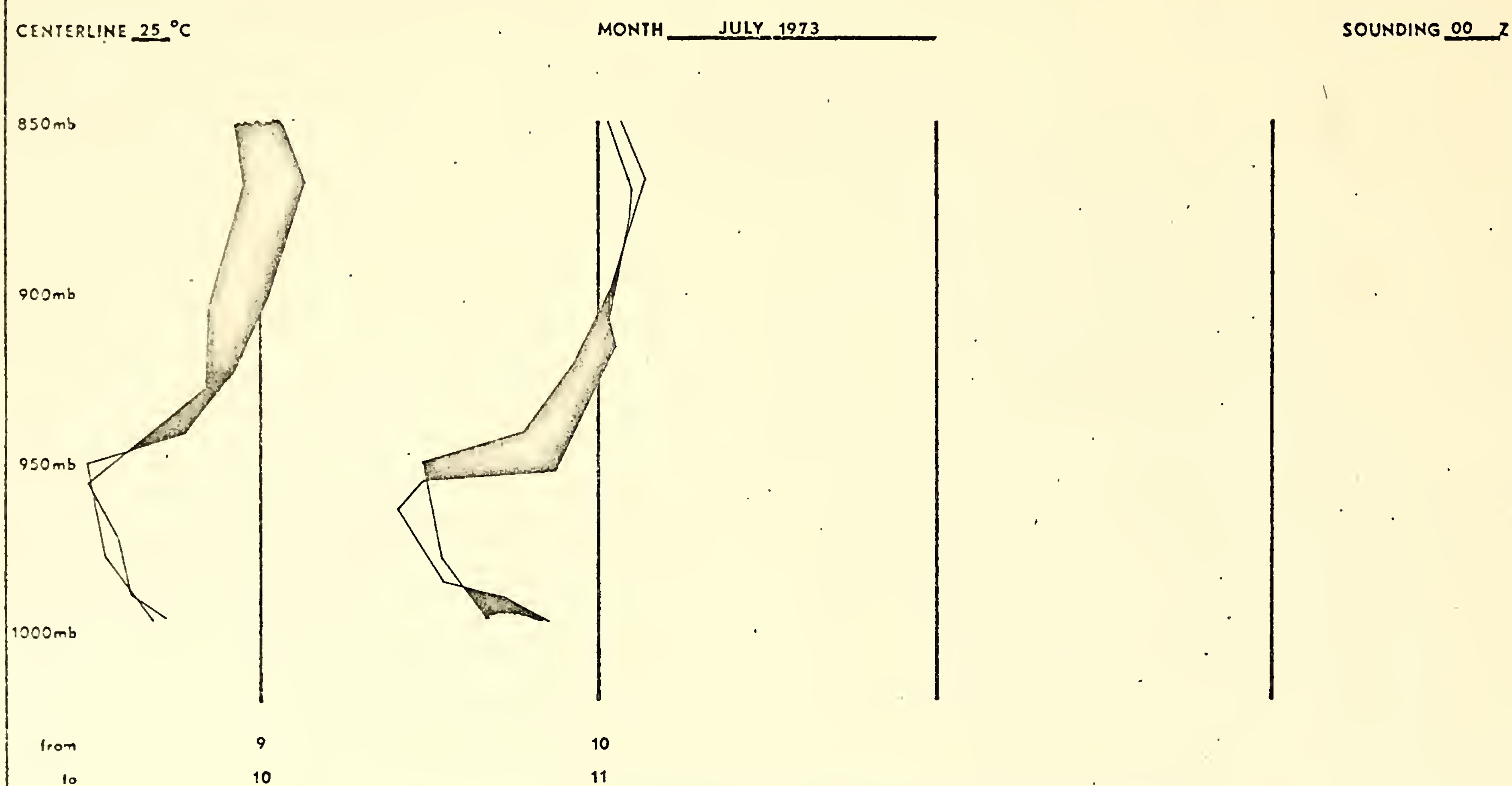

Figure 10c. San Diego. 24-hour sounding changes.
Shaded areas indicate change to warmer temperatures.

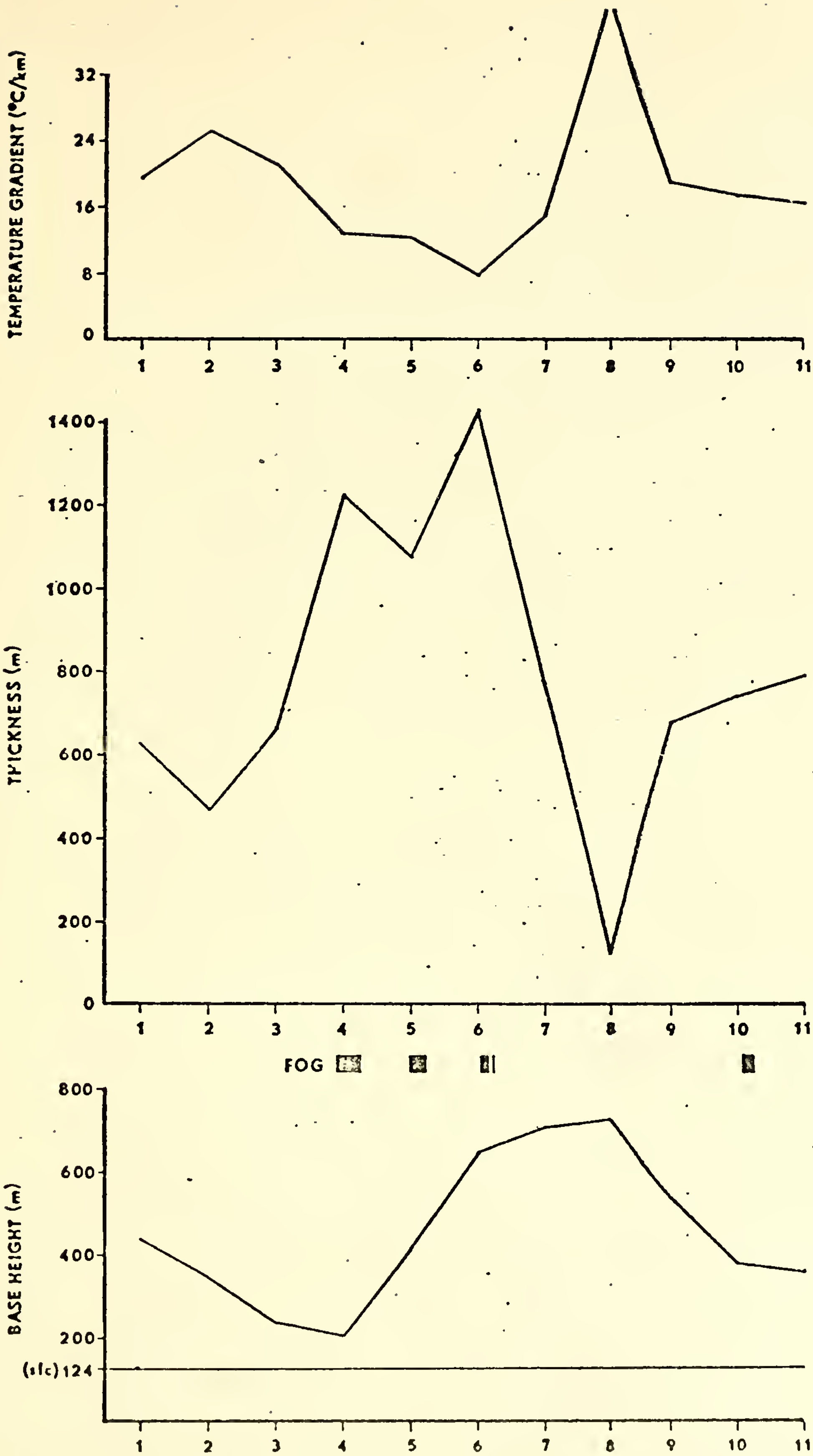

Figure 11. San Diego. Inversion Parameters. July 1973. 12GMT.

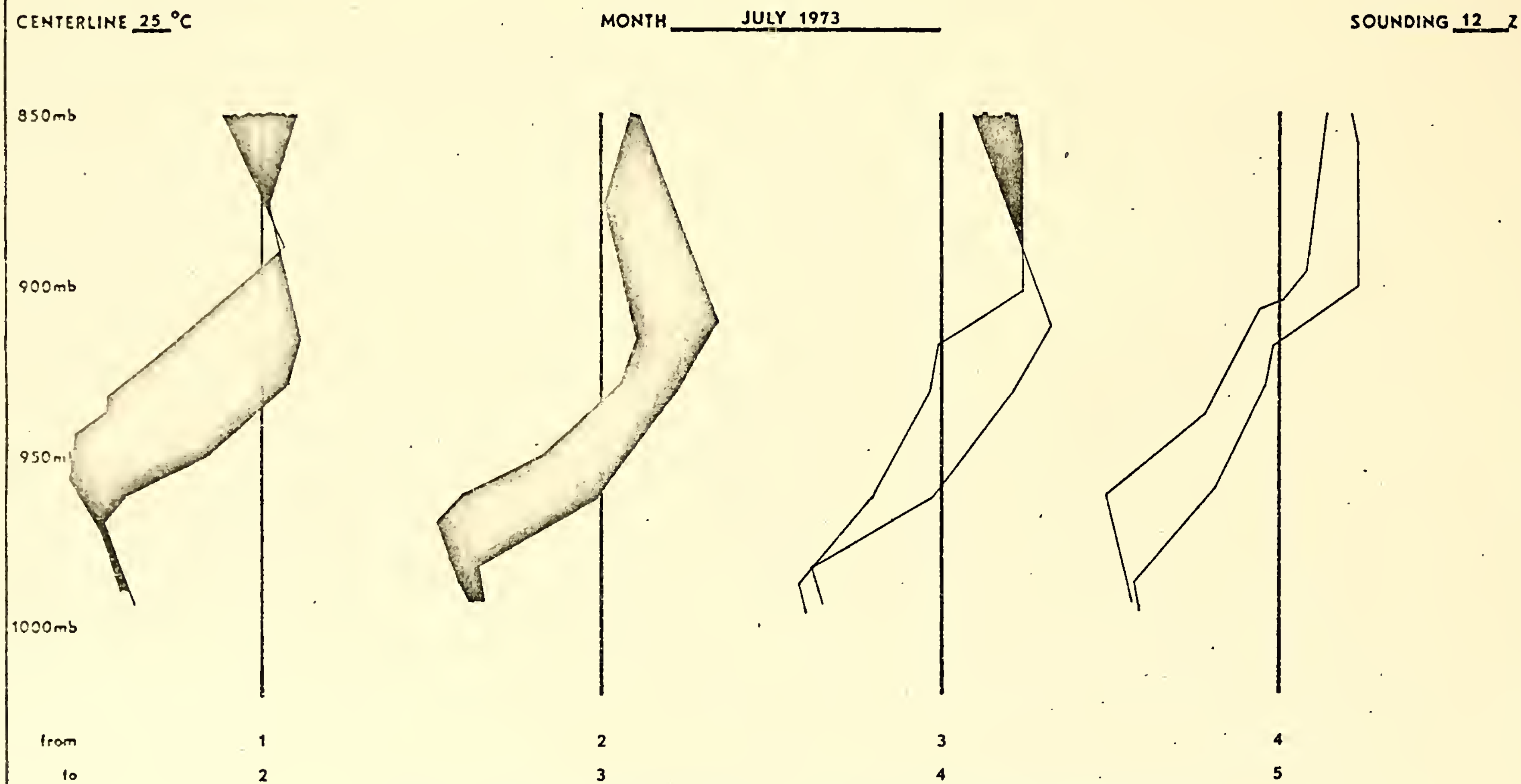

Figure 12a. San Diego. 24-hour sounding changes. Shaded areas indicate change to warmer temperatures.

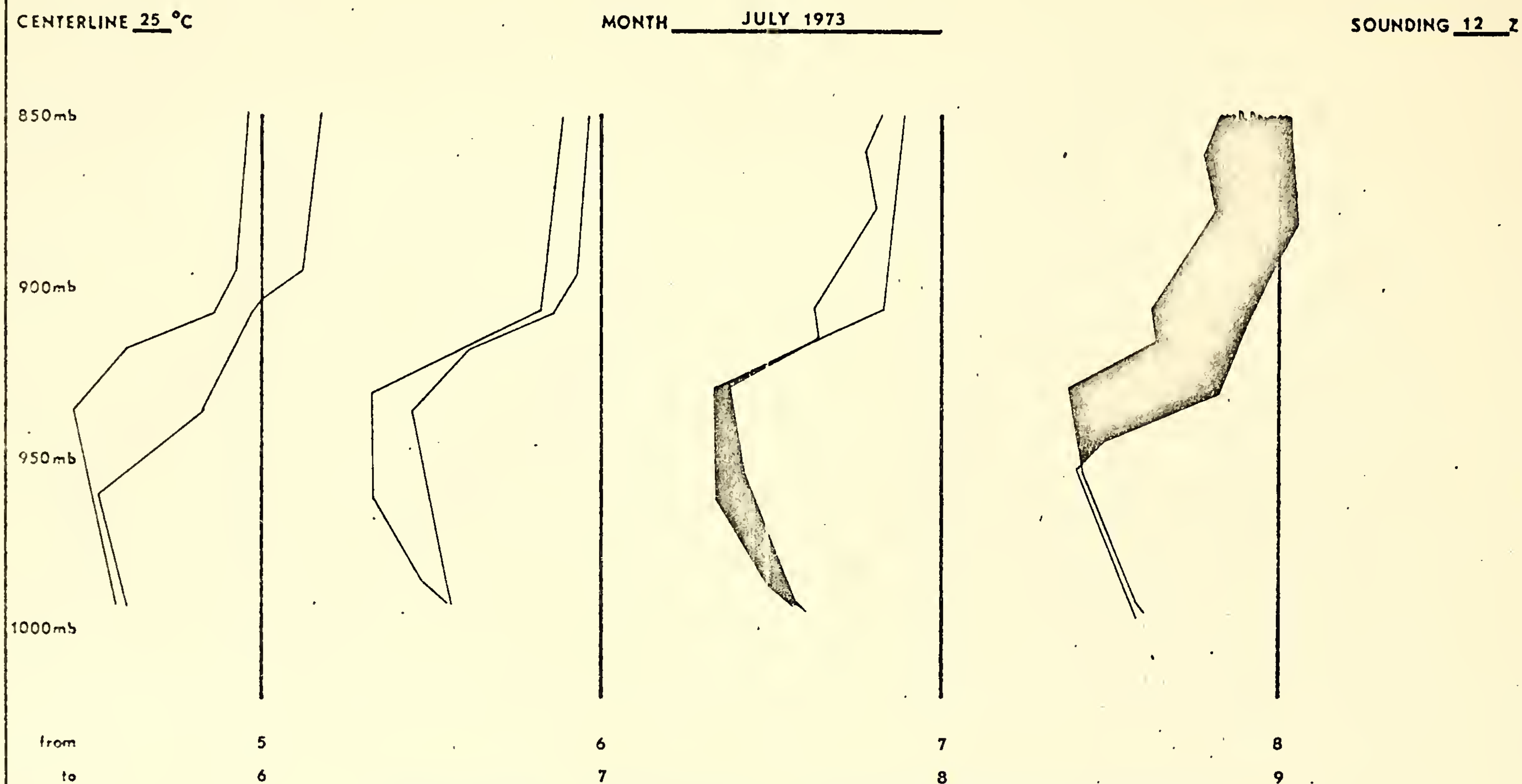

Figure 12b. San Diego. 24-hour sounding changes. Shaded areas indicate changes to warmer temperatures.

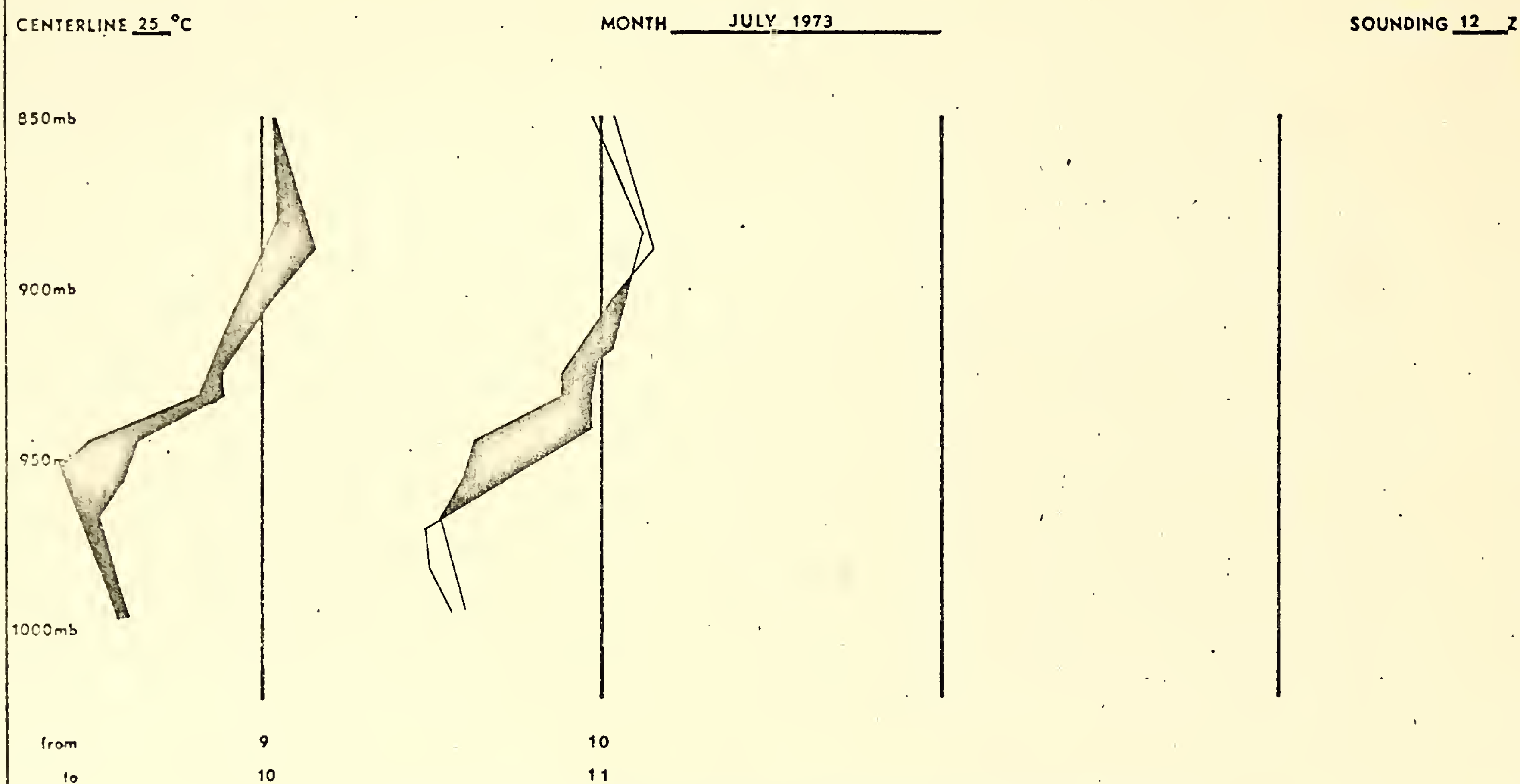

Figure 12c. San Diego. 24-hour sounding change.
Shaded areas indicate change to warmer temperatures.

Case II. San Diego. Winter.

A. Fog occurrence:

11 February 1974; 0510Z to 0730Z; 2 hours 20 minutes
(10) (2110L to 2330L)

B. Discussion for parameter changes found to be consistent:

For the 00Z soundings, an inversion existed below 850 mb on the 10th and 11th, with the height of the base rising. The base of the 12Z inversions is at the surface for the entire period, and, preceding the fog, the inversion layer is weakening. The thickness is increasing while the temperature gradient is decreasing. General thermal changes in the 12Z soundings occur as given in Table 666 in the results section. From the 9th to the 10th, the predominant change below 850 mb is warming with the surface temperature also warming. This indicates fog should occur after the 00Z sounding on the 11th. Fog began at 0510Z on the 11th.

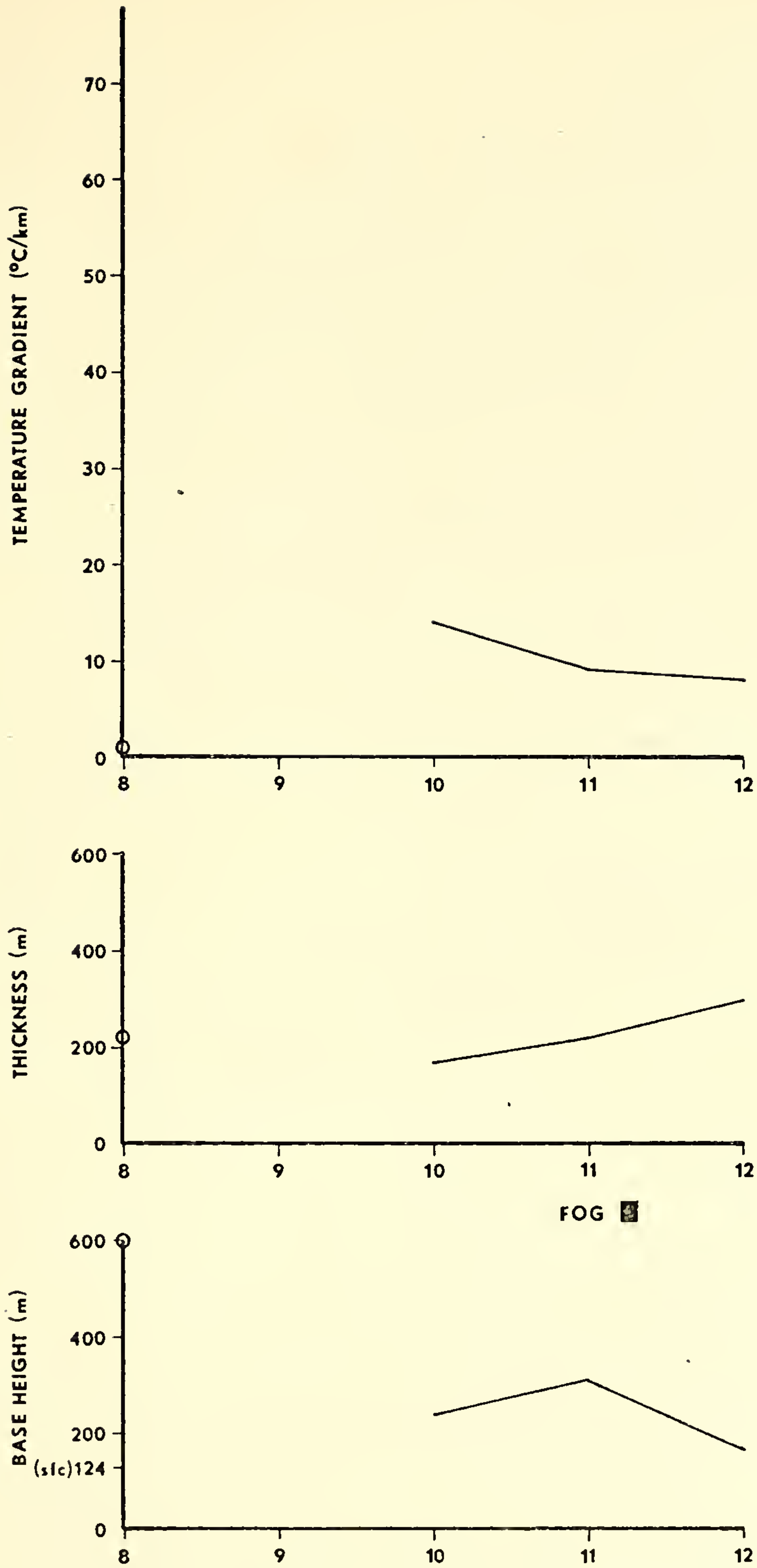

Figure 13. San Diego. Inversion Parameters. February 1974. 00GMT

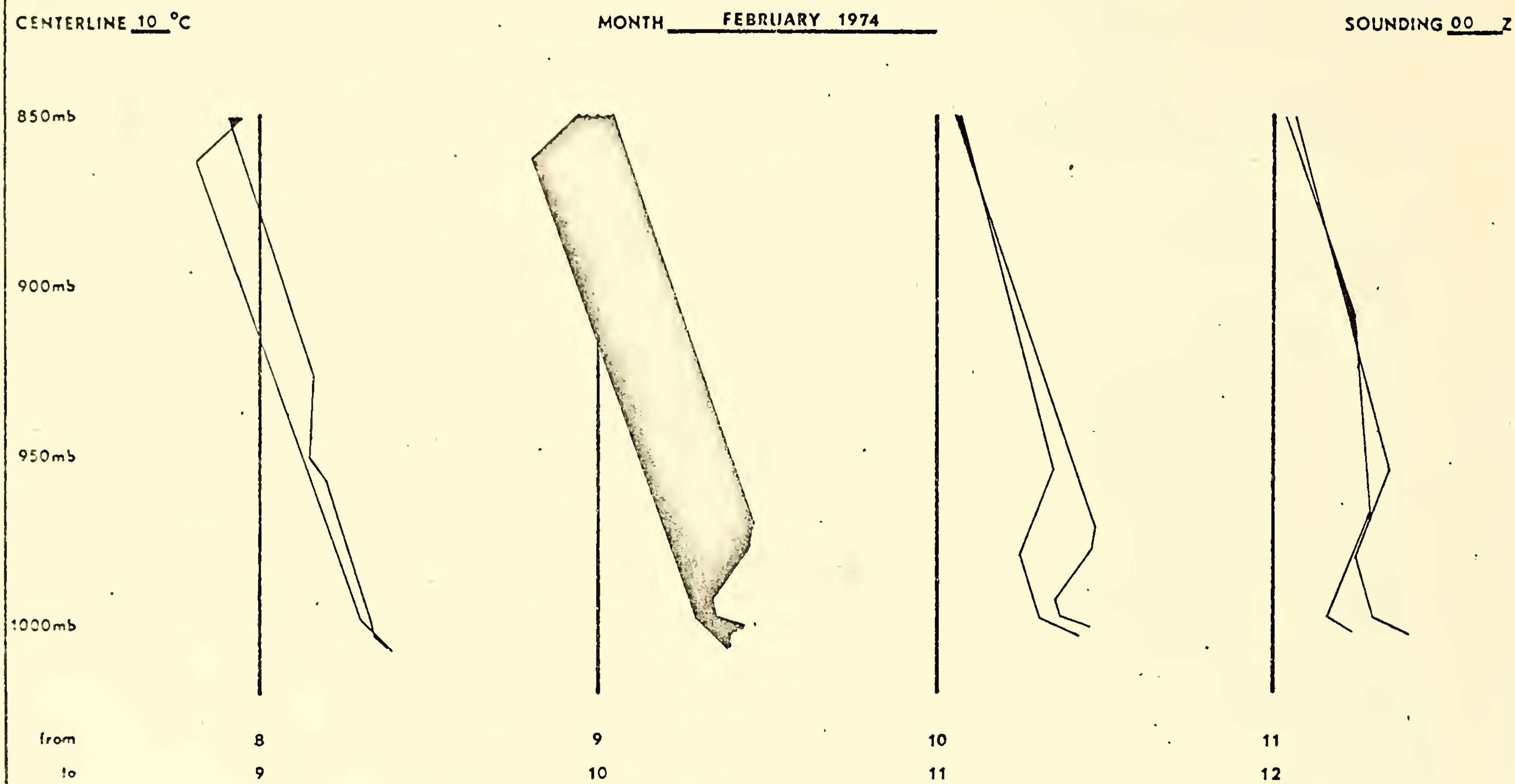

Figure 14. San Diego. 24-hour sounding changes.
Shaded areas indicate change to warmer temperatures.

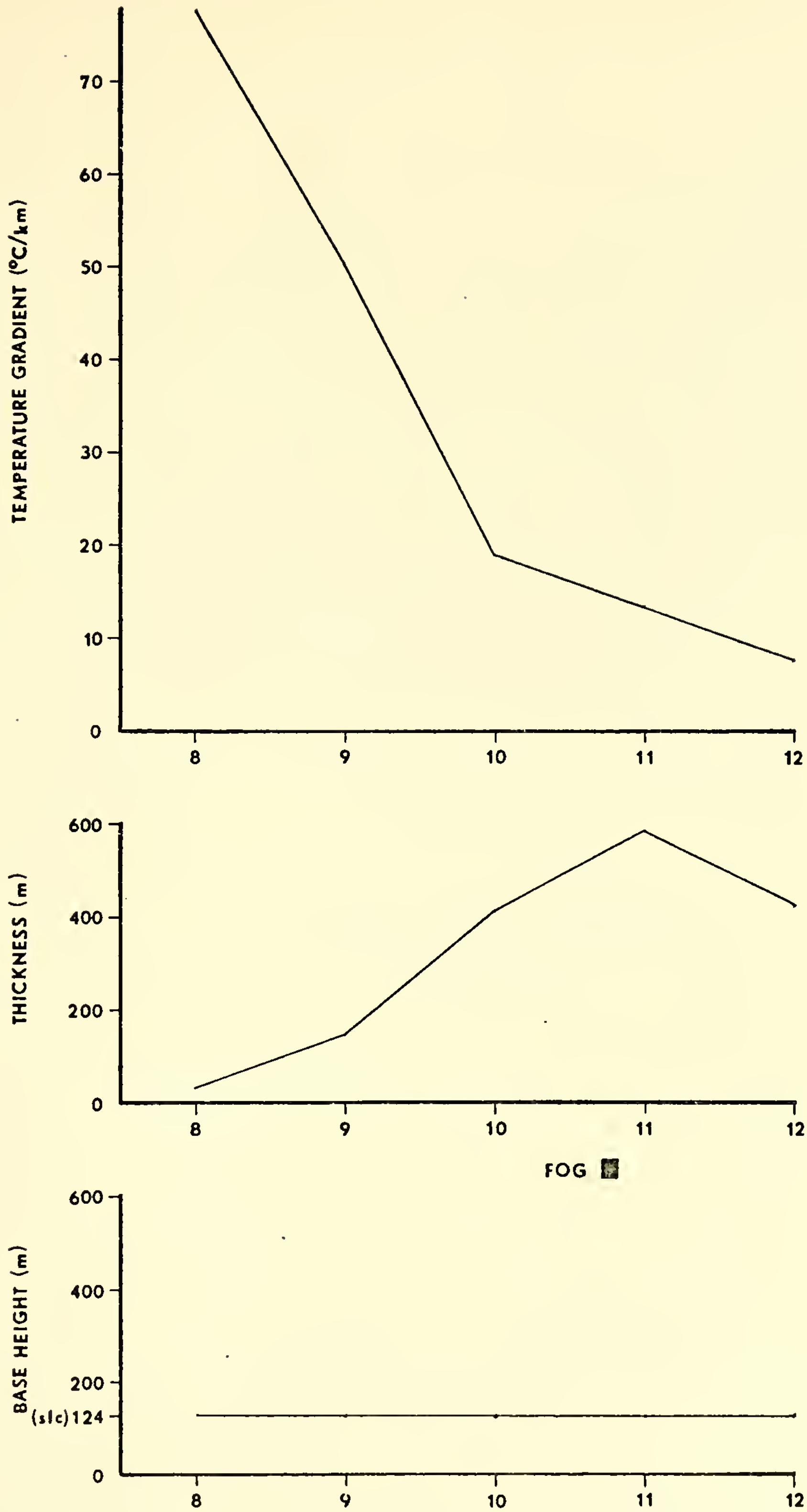

Figure 15. San Diego. Inversion Parameters. February 1974. 12GMT.

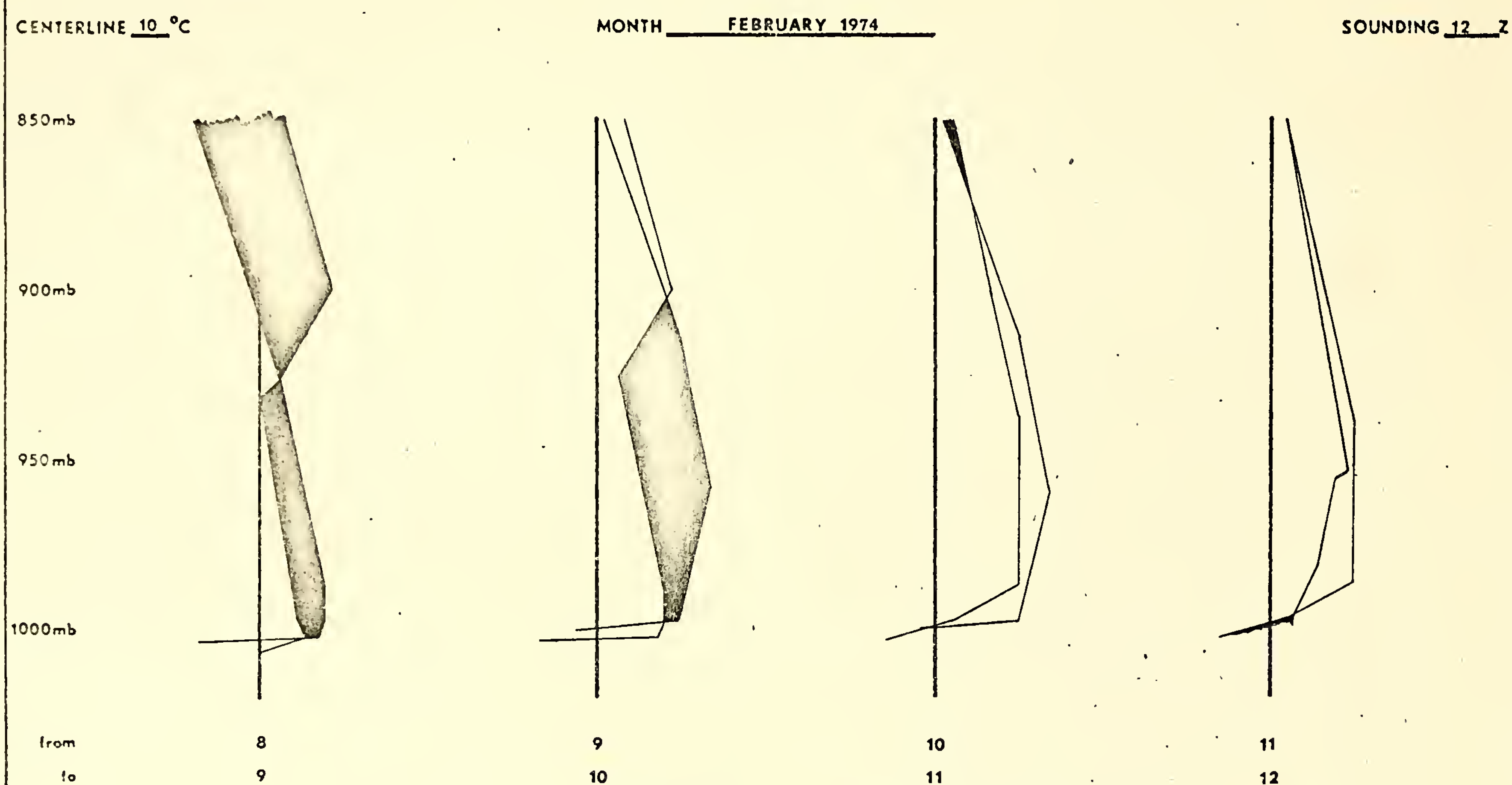

Figure 16. San Diego. 24-hour sounding changes. Shaded areas indicate changes to warmer temperatures.

Case III. Oakland. Summer

A. Fog occurrences:

13 August 1973; 1420Z to 1810Z; 3 hours 50 minutes
(0620L to 1010L)

14 August 1973; 1332Z to 1710Z; 3 hours 38 minutes
(0532L to 0910L)

B. Discussion for parameter changes found to be consistent:

The inversion layer strengthens slightly in the last 24-hour change in 00Z soundings prior to the two-day fog sequence. The 12Z graphs show the inversion base moving downward in the last 24-hour period prior to the fog sequence.

Note: he circled points on the 12Z graphs are for shallow surface inversions which were not considered to be the dominant inversion of concern.

Figures 19 show the 12Z sounding temperatures in the atmosphere, below 850 mb, generally warming from the 9th to the 11th. Cooling of at least the lower portion of the sounding occurs for the 11-12 and 12-13 changes. Fog begins after 12Z on the 13th and 14th.

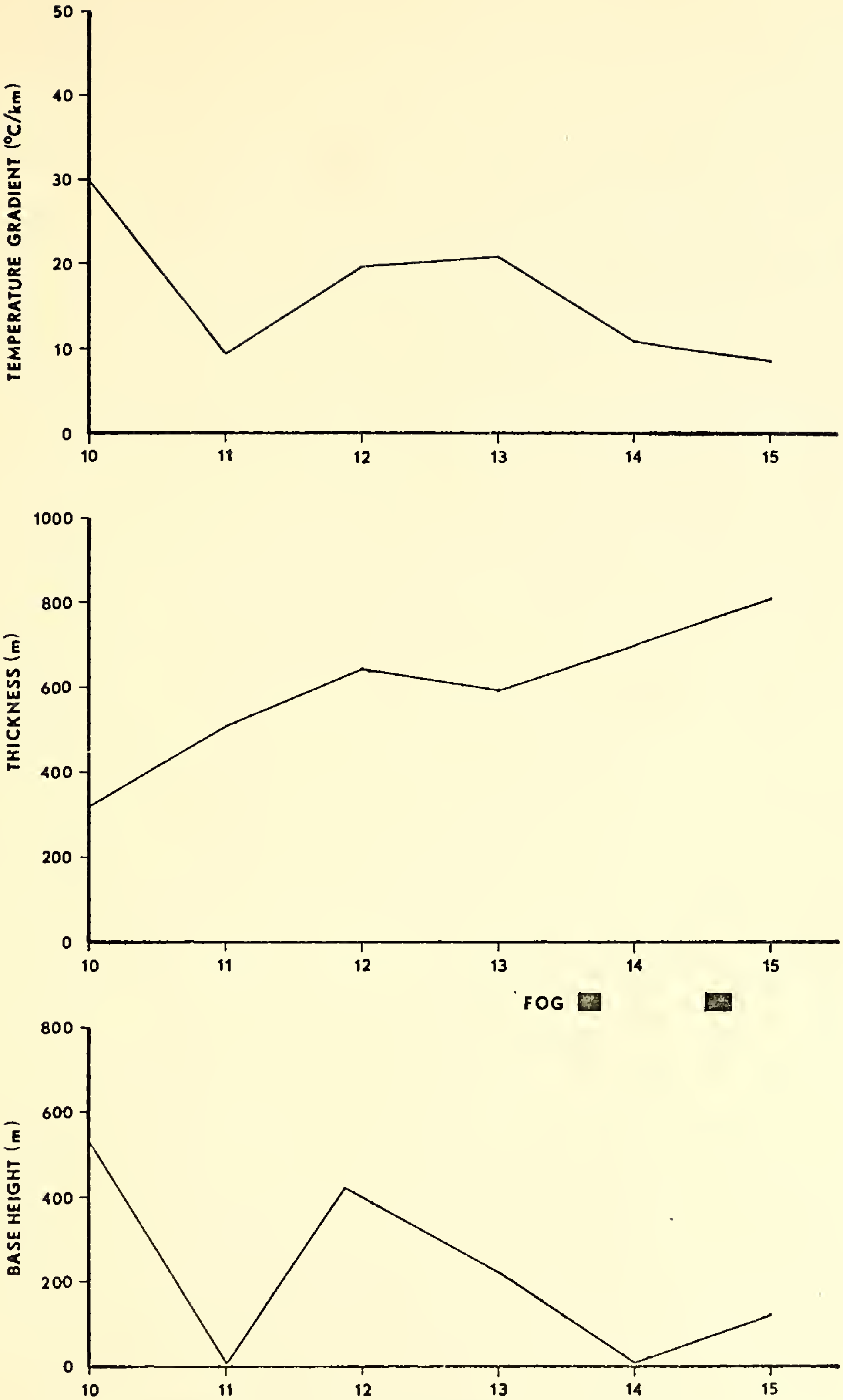

Figure 17. Oakland. Inversion Parameters.
August 1973. 00GMT.

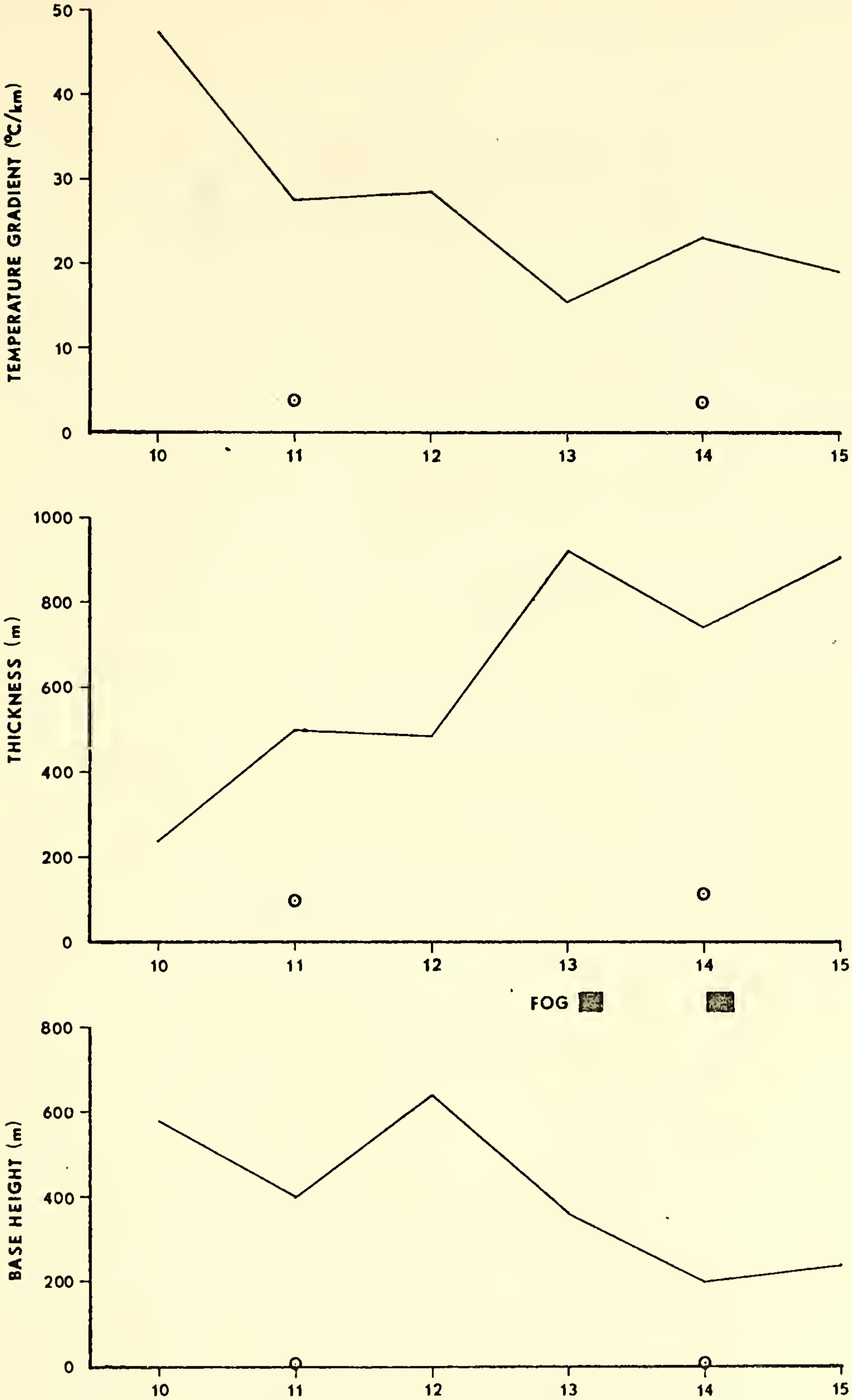

Figure 18. Oakland. Inversion Parameters.
August 1973. 12 GMT.

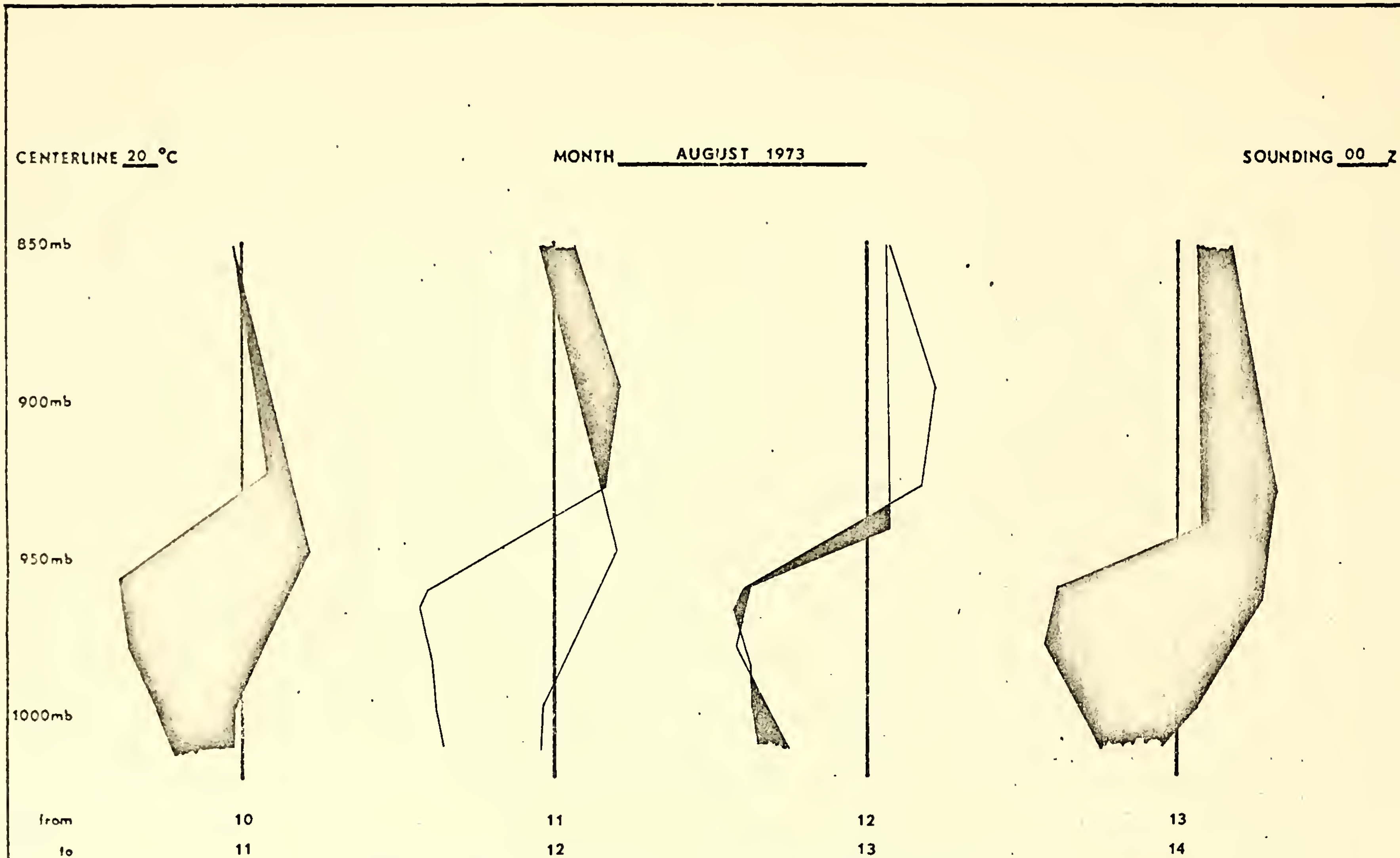

Figure 19a. Oakland. 24-hour sounding changes.
Shaded areas indicate change to warmer changes.

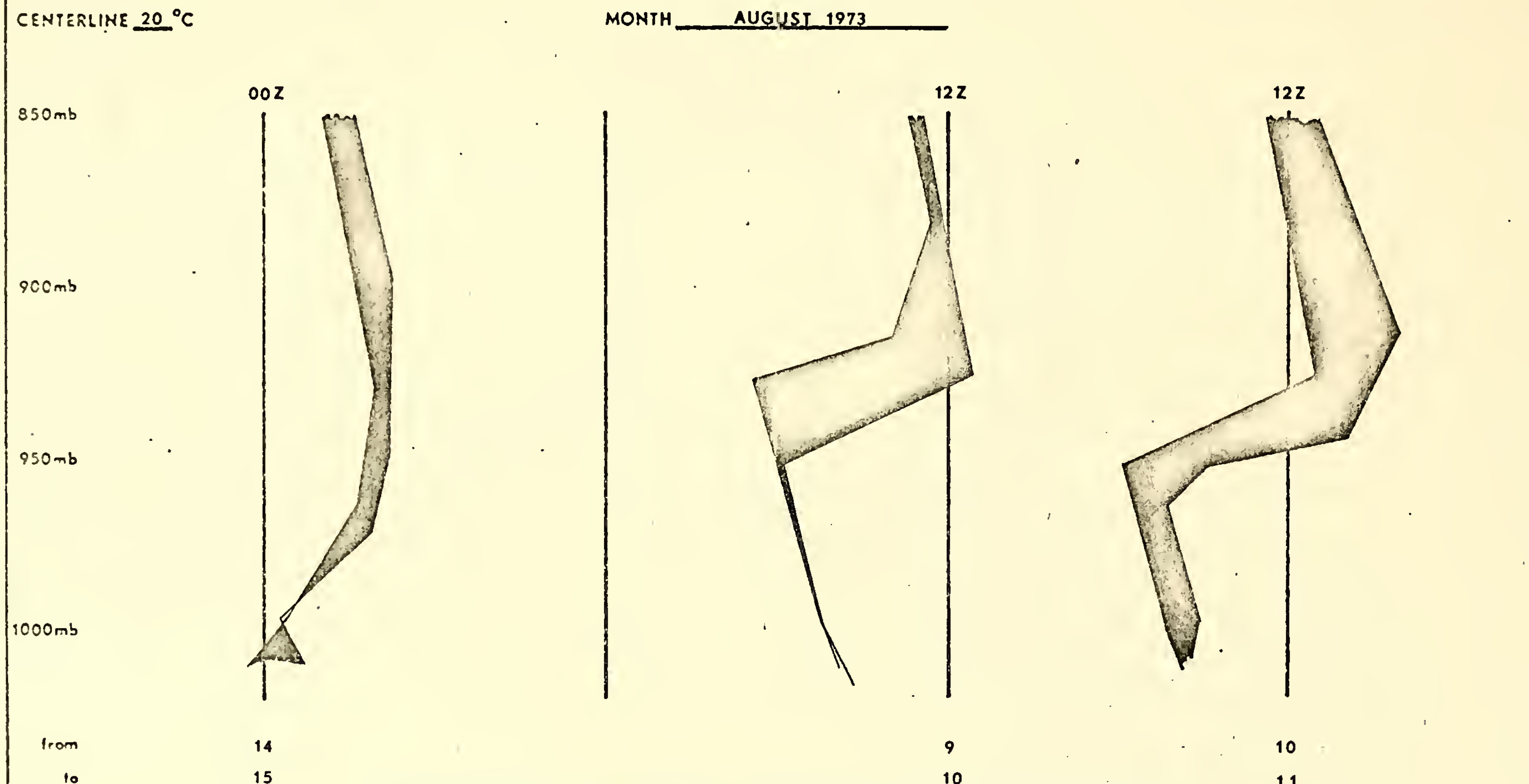

Figure 19b. Oakland. 24-hour sounding changes.
Shaded areas indicate change to warmer temperatures.

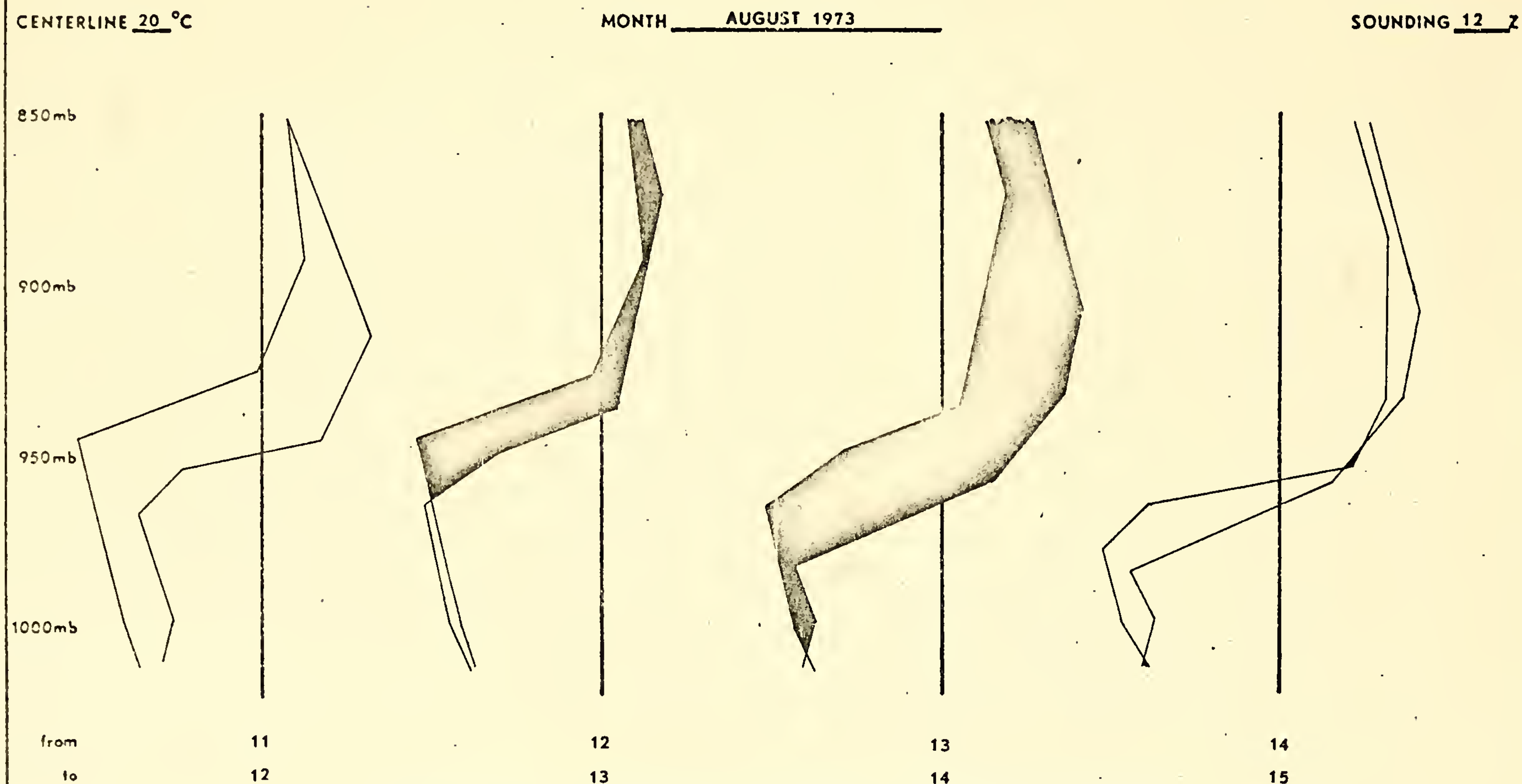

Figure 19c. Oakland. 24-hour sounding changes.
Shaded areas indicate change to warmer temperatures.

Case IV. Oakland. Winter

A. Fog occurrence:

12 January 1974; 1340Z to 2040Z; 7 hours
(0540L to 1240L)

B. Discussion for parameter changes found to be generally consistent.

The inversion layer, during the last 24-hour 00Z period prior to fog, weakens: The thickness increasing while the temperature gradient lessens. In fact, the temperature gradient on the 29th and 30th is less than 1° c/km; almost isothermal.

For the 12Z soundings, the last 24-hour change prior to the onset of fog shows both the thickness and temperature gradient of the inversion layer decreasing from the 28th to the 29th. The base of the inversion is at the surface for three soundings prior to the fog occurrence. This was a characteristic found to be consistent in the months of January and February.

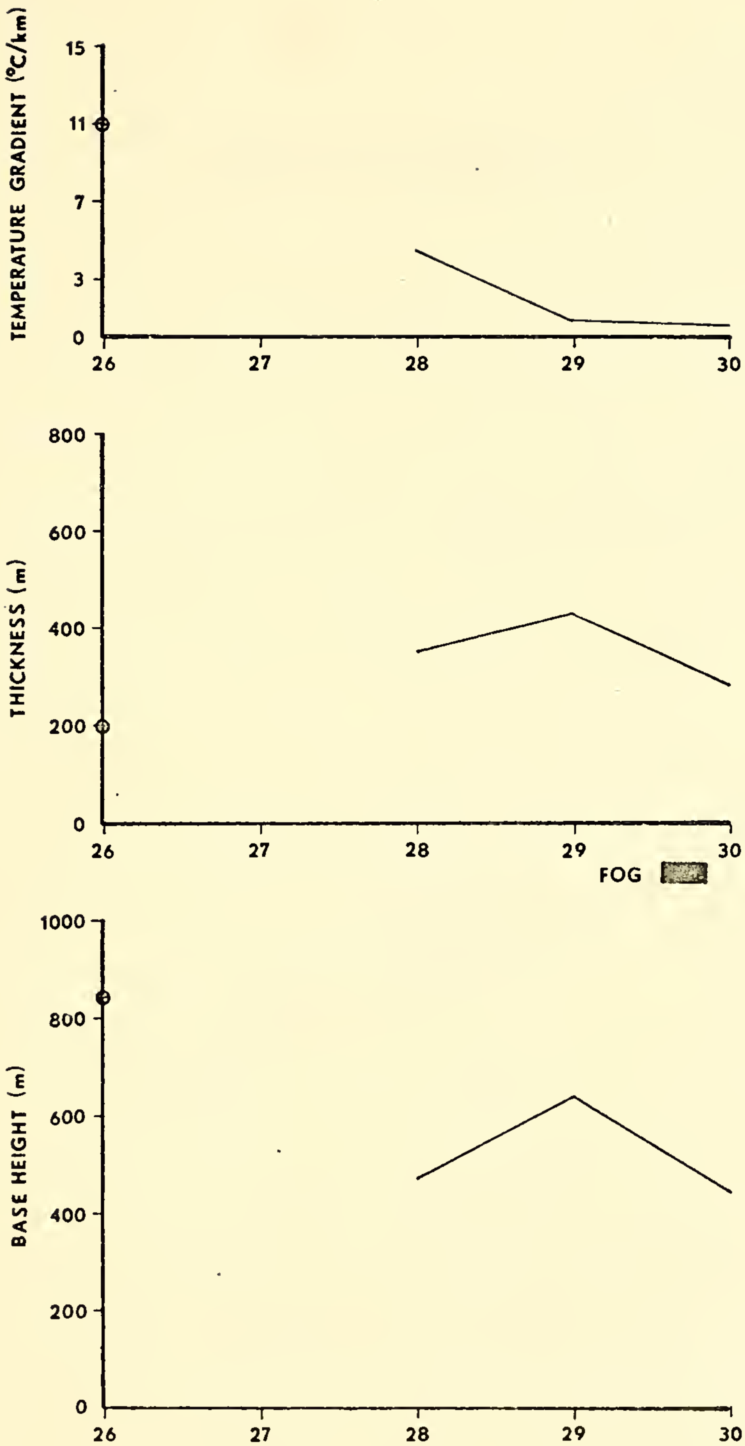

Figure 20. Oakland. Inversion Parameters.
January 1974. 00Z

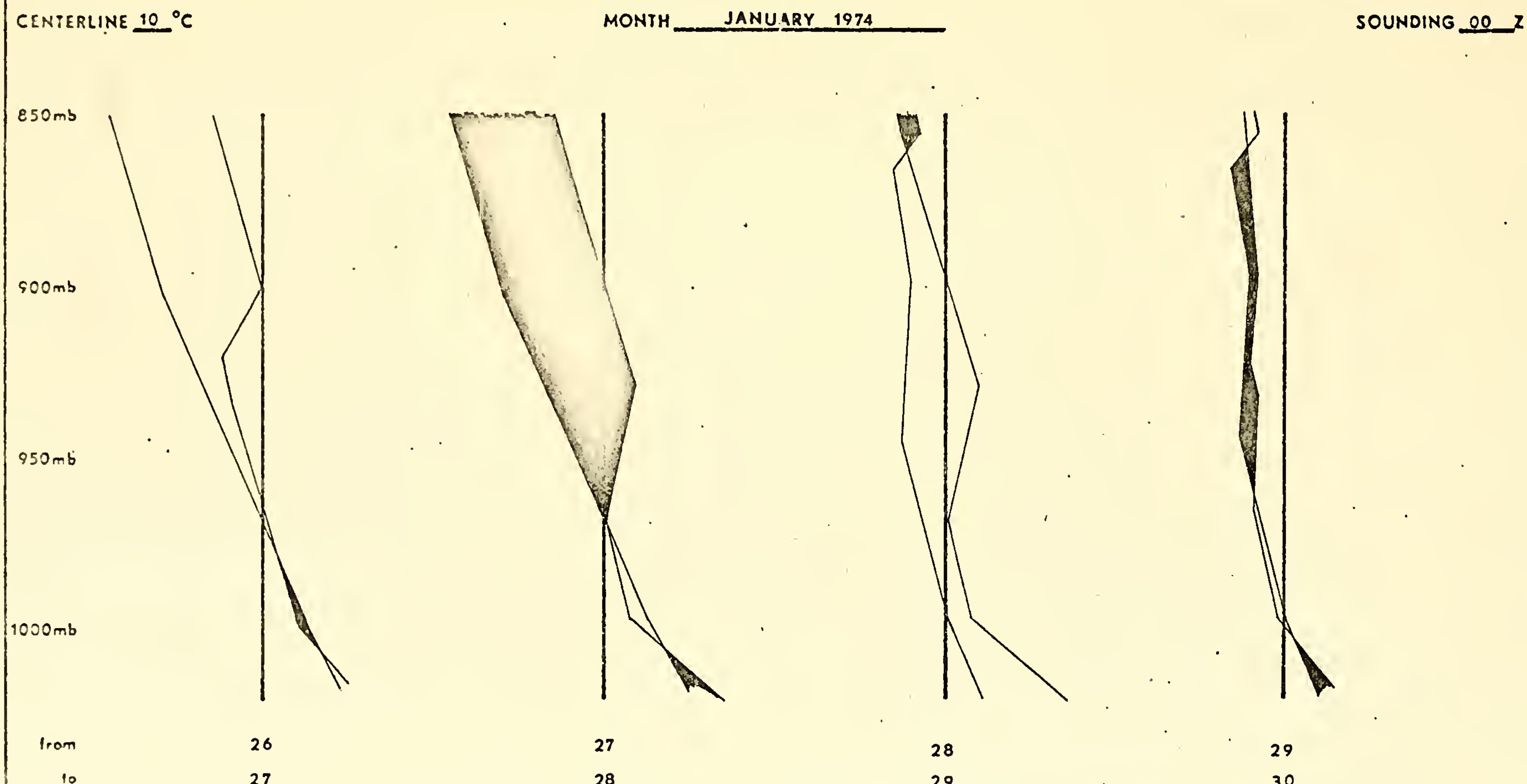

Figure 21. Oakland. 24-hour sounding changes. Shaded areas indicate change to warmer changes.

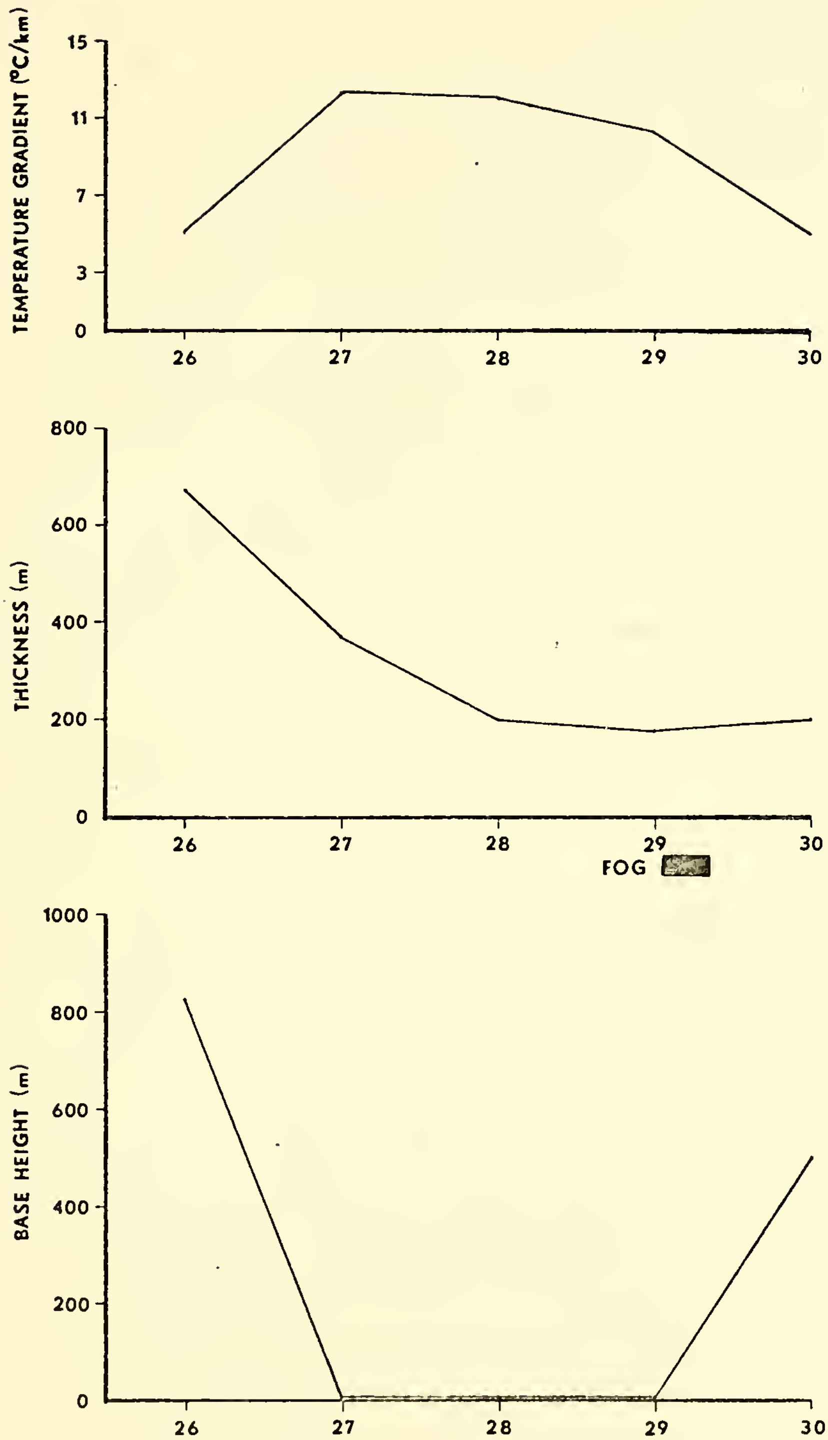

Figure 22. Oakland. Inversion Parameters.
January 1974. 12GMT.

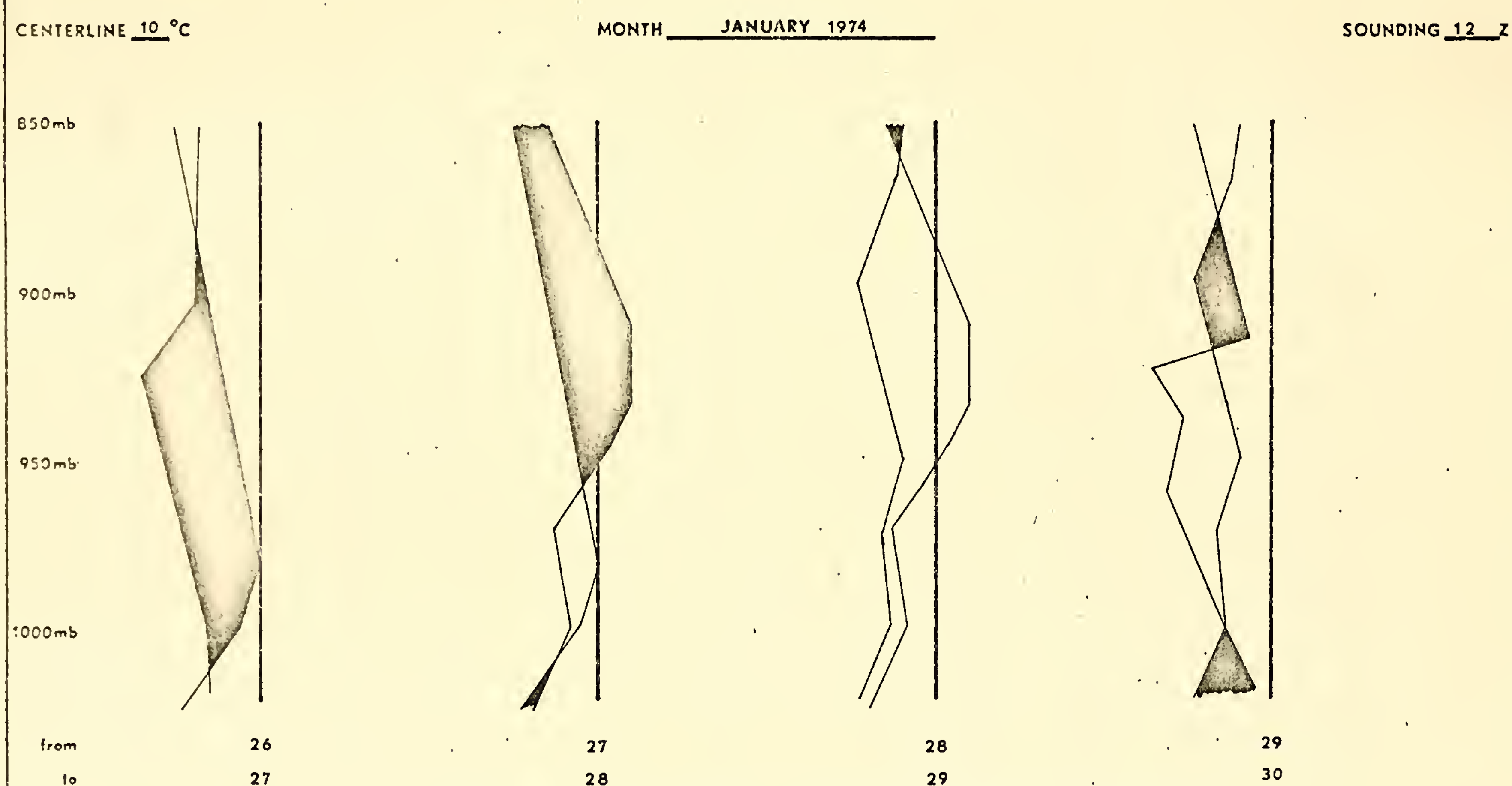

Figure 23. Oakland. 24-hour sounding changes.
Shaded area indicates change to warmer temperatures.

BIBLIOGRAPHY

1. Air Weather Service, 1954: General Aspects of Fog and Stratus Forecasting, AWS Manual 105-44, U.S. Air Force.

2. Edinger, J. G., 1963: "Modifications of the Marine Layer over Coastal Southern California," Journal of Applied Meteorology, V. 2, pp. 706-712.

3. Leipper, D. F., 1948: "California Stratus Forecasting Correlations, 1935 and Other Years," Bulletin of the American Meteorological Society, V. 29, No. 6, pp. 294-297.

4. Leipper, D. F., 1948: "Fog Development at San Diego, California," Sears Foundation: Journal of Marine Research, V. III, No. 3, pp. 337-346.

5. Leipper, D. F., and Others, 1948: "Fog Forecasting on Coasts," Scripps Institution of Oceanography, Final Report of the Fog Project.

6. Leipper, D. F., and Others, 1973: "Observation, Analysis, and Prediction of Marine Fog," Naval Postgraduate School Department of Oceanography, Annual Report from 1 July 1972 to 30 June 1973.

7. Leipper, D. F., and Others, 1968: "The Sharp Smog Bank and California Fog Development," Bulletin of the American Meteorological Society, V. 29, No. 4, pp. 354-358.

8. Naval Weather Service, 1972: "Local Area Forecaster's Handbook," Naval Weather Service Facility, Alameda, California, pp. I-25 - I-27.

9. Naval Weather Service, 1973: "Local Area Forecaster's Handbook," NAS North Island, NWS Facility, San Diego, California, pp. 10-15.

10. Naval Weather Service, 1970: "Local Area Forecaster's Handbook," NAS Whidbey Island, NWS Environmental Detachment, Oak Harbor, Washington, p. 7.

11. Naval Weather Service, 1963: "Local Area Forecaster's Handbook," U.S. Naval Air Station, Seattle, Washington, pp. 49-52.

12. Rosenthal, J., 1968: Observed Inversion Fluctuations on the Synoptic Scale," Pacific Missile Range, Point Mugu, California.

13. Schroeder, M. J., and Others, 1967: "Marine Air Invasion of the Pacific Coast: A Problem Analysis," Bulletin of the American Meteorological Society, V. 48, pp. 802-808.

14. Weather Division Headquarters Army Air Forces, Report No. 30 (Revised), 1944: "Fog and Low Ceiling Frequencies Along the U.S. Pacific Coast."

INITIAL DISTRIBUTION LIST

		No. Copies
1.	Commander, Naval Weather Service Command Naval Weather Service Headquarters Washington Navy Yard Washington, D. C. 20390	1
2.	Department of Oceanography, Code 58 Naval Postgraduate School Monterey, California 93940	3
3.	Dr. Robert E. Stevenson Scientific Liaison Office, ONR Scripps Institution of Oceanography La Jolla, California 92037	1
4.	SIO Library University of California, San Diego P. O. Box 2367 La Jolla, California 92037	1
5.	Department of Oceanography Library University of Washington Seattle, Washington 98105	1
6.	Department of Oceanography Library Oregon State University Corvallis, Oregon 97331	1
7.	Commanding Officer Fleet Numerical Weather Central Monterey, California 93940	1
8.	Commanding Officer Environmental Prediction Research Facility Monterey, California 93940	1
9.	Defense Documentation Center Cameron Station Alexandria, Virginia 22314	12
10.	Library (Code 0212) Naval Postgraduate School Monterey, California 93940	2

11. National Center for Atmospheric Research 1
Library Acquisitions
Boulder, Colorado 80301

12. Dr. James L. Kassner, Jr. 1
Graduate Center for Cloud Physics Research
University of Missouri,
Rolla, Missouri 65401

13. Naval Weather Service Command 1
Naval Weather Service Headquarters
Washington, D. C. 20390

14. Air Weather Service 1
(AWVAS/TF)
Scott AFB, Illinois 62225

15. Dr. G. J. Haltiner, Code 51 2
Department of Meteorology
Naval Postgraduate School
Monterey, California 93940

16. Dr. Robert J. Renard, Code 51 1
Department of Meteorology
Naval Postgraduate School
Monterey, California 93940

17. Prof. Charles L. Taylor, Code 51 5
Department of Meteorology
Naval Postgraduate School
Monterey, California 93940

18. Dr. Glenn W. Jung, Code 58 1
Department of Oceanography
Naval Postgraduate School
Monterey, California 93940

19. Dr. Dale F. Leipper, Code 58 1
Department of Oceanography
Naval Postgraduate School
Monterey, California 93940

20. Lt. Robert J. McClure 2
1235 Paula Drive
Campbell, California 95008

21. Dr. Alan Weinstein 1
Stratiform Cloud Physics Br.
Meteorology Laboratory
Department of the Air Force
Air Force Cambridge Res. Lab.
Laurence G. Hanscom Field
Bedford, Mass. 01730

22. Dr. Pierre St. Amand 1
Earth and Planetary Sci. Div.
Code 602
Department of the Navy
Naval Weapons Center
China Lake, California 93555

23. Mr. Murray H. Schefer 1
AIR-370C
Naval Air Systems Command
Washington, D. C. 20360

24. Dr. Lothar Ruhnke 1
Naval Research Laboratory
Washington, D. C. 20390
Code 8320

25. Dr. Patrick Squires 1
Desert Research Institute
University of Nevada
Reno, Nevada 89507

26. Dr. Thomas E. Hoffer 1
Desert Research Institute
University of Nevada
Reno, Nevada 89502

27. Mr. James Hughes 1
Office of Naval Research
Code 412
Arlington, Virginia 22217

28. Mr. Paul R. Lowe 1
Environmental Prediction Research
Facility
Naval Postgraduate School
Monterey, California 93940

29. Mr. Edward Barker 1
Environmental Prediction
Research Facility
Monterey, California 93940

30. Mr. Roland Pilie 1
Calspan Corporation
Buffalo, New York 14221

31. Dr. Dee F. Taylor 1
Naval Air Systems Command
AIR-540
Washington, D. C. 20360

155917

Thesis
M177 McClure
c.1 The relationship of
temperature inversions
to marine advection fog.